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CHEMICAL ARITHMETIC

CHEMICAL ARITHMETIC

WITH

TWELVE HUNDRED EXAMPLES

BY

SYDNEY LUPTON, M.A., F.C.S.

London
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PREFACE.

THE following numerical problems on the chief properties and reactions of the more important elements and inorganic compounds are intended to be used in conjunction with a descriptive text-book of chemistry.

The beginner is supposed to be acquainted with elementary arithmetic. Those more advanced are strongly advised to learn the *use* of logarithms, when Tables VI. and VII. will materially lighten the arithmetical labour.

Those portions of the introduction, which may be omitted on a first perusal, and a few of the more difficult problems, are marked off by lines.

For the sake of simplicity, and to avoid frequent changes, in many cases the numbers used are only approximate. More accurate data will be found in my "Numerical Tables and Constants in Elementary Science."

The mass of a litre of oxygen, 1·42961 gm., is known more accurately than that of any other elementary gas (cf. *Nature*, Ap. 13, 1893), and it is convenient to assume O = 16 as the basis of the system of atomic weights. Hence "two volumes" are equal to 32/1·42961 = 22·3837 l., and the "crith"

a mean of the two of the standard hydrogenous gas is 1·8995 gm. For purposes of elementary instruction it is sufficiently correct to adhere to the time-honoured "absolute volume," 11·2 l., of Williamson, and the "unit" 0·0895 gm., of Hofmann.

S. L.

London, July, 1898.

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CHEMICAL ARITHMETIC.

(1.) Mass Volume and Density.

The mass (M) of or quantity of matter in a body remains constant so long as nothing is added to or taken from the body.

The volume (V) or bulkiness of a body varies with the conditions, such as pressure and temperature, to which it is subjected.

The density (Δ) of a body is measured by the number of units of mass contained in the unit of volume of it.

$$\text{Hence } M = V\Delta. \quad V = \frac{M}{\Delta}. \quad \Delta = \frac{M}{V}.$$

In the metric system the density of a solid or liquid is expressed by the number of grams in a cubic centimetre of it, or by the number of kilograms in a litre of it. Since a cubic centimetre of water weighs very nearly a gram, the density of a solid or liquid may also be expressed by the number of times it is heavier than an equal volume of water.

Thus the expression that the density of copper is 8·9 means that a cubic centimetre of copper weighs 8·9 grams, or is 8·9 times as heavy as an equal volume of water. From this it follows that 1000 ccm. of copper contain $1000 \times 8{\cdot}9 = 8900$ gm., and that 1000 gm. of copper occupy $\frac{1000}{8{\cdot}9} = 112{\cdot}36$ ccm.

From these relations many questions connected with changes in volume and density, when substances mix or combine, can be solved.

If metals having volumes V_1 V_2 V_3 and densities Δ_1 Δ_2 Δ_3 are melted together to form an alloy of volume V_4 and density Δ_4, since the melting produces no change in the mass :—

$$V_1\Delta_1 + V_2\Delta_2 + V_3\Delta_3 = V_4\Delta_4.$$

Again if masses of metals M_1, M_2, M_3, form an alloy of mass M_4 without permanent change of volume :—

$$\frac{M_1}{\Delta_1} + \frac{M_2}{\Delta_2} + \frac{M_3}{\Delta_3} = \frac{M_4}{\Delta_4}.$$

Thus to find the density of the native alloy (Hg_3Au_2) of 600 parts of mercury (Δ 13·59) and 393·2 parts of gold (Δ 19·3) supposing that no contraction takes place :—The mass of the alloy is 600 + 393·2 grams.

$$\frac{600}{13{\cdot}59} + \frac{393{\cdot}2}{19{\cdot}3} = \frac{993{\cdot}2}{\Delta_4} \qquad \therefore \Delta_4 = 15{\cdot}4.$$

The density is found by experiment to be 15·47, hence a small contraction takes place during the combination.

In the English system the density of a solid or liquid is measured by the number of pounds in one cubic foot of it ; and the number of times a solid or liquid is heavier than water is spoken of as its specific gravity.

Since a cubic foot of water weighs 62·4 lb., the density of a solid or liquid according to the English system is 62·4 times its specific gravity.

Thus mercury is 13·59 times as heavy as water (specific gravity), and a cubic foot of it weighs 13·59 × 62·4 = 848·016 lb. (density).

Weight.

The mass of a body is in practice usually measured by its weight, that is by the attraction of the earth upon it. This attraction is equal to the mass of the body multiplied by (g) the velocity which it would acquire by falling freely in vacuo for a second under the influence of the attraction of the earth.

$$W = Mg \text{ (where } g = 981 \text{ cm. in London).}$$

The acceleration due to the attraction of the earth (g) increases as a body passes from the Equator to the Pole, because it comes nearer to the centre of the earth, and is also less affected by the rotation of the earth. Hence the weight of a body varies with its geographical position and distance from the sea-level.

If the masses of two bodies at different places were compared by estimating their weights with spring-balances, a correction for the difference of gravity at the two places would have to be introduced. But in practice the masses of bodies are determined by comparing them in a balance with pieces of metal of known mass

("weights") on which the earth exercises an equal attraction. Hence in a balance masses and not weights are in reality estimated.

The word weight is often used when mass is really meant, *e.g.* a gram or a pound is a unit of mass and not a unit of weight.

(2.) Fluid Pressure.

Most liquids such as water and mercury are found to decrease in volume very slightly under increased pressure, hence they are spoken of as "incompressible" fluids. Gases and a few liquids of very low boiling point decrease in volume considerably under increased pressure and are spoken of as "compressible" fluids.

Fluids are found to transmit pressure equally in all directions, and it is often convenient to measure pressures by the lengths of columns of incompressible fluids which produce pressures equal to those which are to be measured.

(i.) The pressure P on the layer of mercury at the bottom of a tube 76 cm. long and 1 scm. in area is equal to the weight of the mercury (Δ 13·596) above it.

$$P = Mg = 76 \times 1 \times 13{\cdot}596 \times g = 1033{\cdot}3 \times g \text{ gm.}$$

or P = the weight of 1033·3 gm.

(ii.) The pressure then of a column of liquid 1 scm. in area is expressed by the height of the column in cm. × the density of the liquid (g is neglected as constant for the same place).

Hence two columns of two liquids of heights H_1 H_2 and densities Δ_1 and Δ_2 produce equal pressures if $H_1\Delta_1 = H_2\Delta_2$.

Thus to find the height of a column of mercury (Δ 13·59) which will produce the same pressure as a column of water (Δ 1) 217 mm. high.

$$H_1 \times 13{\cdot}59 = 21{\cdot}7 \times 1. \qquad H_1 = 1{\cdot}596 \text{ cm.} = 15{\cdot}96 \text{ mm.}$$

(iii.) Suppose a solid of mass M, such as an hydrometer, float in a liquid of density Δ with a volume V immersed. The weight of the hydrometer presses downwards, and a pressure equal to that of the liquid displaced acts upwards :—

$$Mg = V\Delta g$$

$$\Delta = \frac{M}{V}.$$

Or the mass of the hydrometer divided by the volume of it which is immersed gives the density of the liquid in which it floats.

(iv.) When substances are weighed, they are usually in air and hence appear to weigh less than they really do by a weight equal to

that of the air displaced. The weights are also affected by the same cause. Hence if V_s be the volume of the substance, and V_w the volume of the weights in cubic centimetres; and a the mass of 1 ccm. of air at $t°$ C. and with the barometer standing at H mm.

The real mass of the substance is equal to the mass of the weights

$$+ a(V_s - V_w); \text{ where } a = \frac{0{\cdot}001293 \times H}{(1 + {\cdot}00367t) \times 760}. \quad (6.)$$

(3.) THE BAROMETER.

The barometer in its most simple form consists of a tube about 1 cm. across and 80 cm. long, closed at one end, filled with mercury, and inverted in a vessel of mercury. Since fluids transmit pressure equally in all directions, the pressure of the atmosphere on 1 scm. of surface of the mercury in the vessel is equal to that on 1 scm. of mercury at the same level in the tube. Hence the weight of the mercury in the tube measures the pressure of the air outside.

The standard pressure of the air, called an atmosphere, is taken as equal to that of a column of mercury 760 mm. or 76 cm. high. The pressure of an atmosphere then (2. i.) is equal to that of 1·0333 kilog. on the scm. or 14·7 lb. on the square inch.

Since increase of temperature causes the mercury to expand and become less dense, and the scale to become longer, a correction must be applied for any temperature $t°$ C. (6). If the reading on a brass scale be h mm. the true height H is—

$$H = h\,\frac{(1 + {\cdot}000019t)}{(1 + {\cdot}00018t)} = h\,(1 - {\cdot}00016t).$$

The higher a barometer is carried above sea-level the less is the action of gravity upon the mercury and the shorter is the column of air above the instrument. Hence for each 10·5 m. through which the instrument is raised the mercury falls about 1 mm. This only applies to small elevations. Or for each metre that the place of observation is above sea-level about ·095 mm. must be added to the apparent height of the mercury.

The difference in height in metres D between two places at $T°$ C. and $t°$ C. where the barometer stands at H and h m. is given by the formula :—

$$D = 16000\left[1 + \frac{2(T + t)}{1000}\right] \times \frac{H - h}{H + h}.$$

(4.) The Change in Volume of a Mass of Gas produced by Change of Pressure.

Boyle's Law.—The volume of a mass of gas varies inversely as the pressure upon it.

Hence the volume (v) of a mass of gas multiplied by the pressure upon it (p) is equal to the new volume (V) of the same mass of gas multiplied by the new pressure (P).

$$VP = vp \quad \text{or} \quad V = \frac{vp}{P}.$$

Thus to find the new volume if 250 ccm. of gas under the pressure 742 mm. have the pressure increased to 760 mm.

$$V = \frac{250 \times 742}{760} = 244{\cdot}08 \text{ ccm.}$$

(5.) Thermometers.

The temperature or hotness of bodies is usually measured by thermometers, which generally consist of enclosed volumes of air or mercury from the expansion of which the temperature is determined.

In every case two "fixed points" are taken, the melting-point of ice, and the boiling-point of water under a pressure of 760 mm. of mercury. The difference in temperature between these two fixed points is divided into a number of equal degrees, and the graduation is carried above and below the fixed points.

Three different scales are in use :—

	Melting of Ice.	Interval.	Boiling-point.
The Centigrade scale	0° C.	100° C.	100° C.
Fahrenheit's scale	32° F.	180° F.	212° F.
Réaumur's scale	0° R.	80° R.	80° R.

Since the difference in temperature between the two fixed points is the same in each case,

$$100° \text{ C.} = 180° \text{ F.} = 80° \text{ R,}$$
$$\text{or} \quad 5° \text{ C.} = 9° \text{ F.} = 4° \text{ R.}$$

Hence any given number of degrees a on one scale can be expressed on another scale by the following formulæ :—

$$\frac{(a° \text{F.} - 32)\,5}{9} = x° \text{ C.} \qquad \frac{(a° \text{ F.} - 32)\,4}{9} = x° \text{ R.}$$

$$\frac{a° \text{ C.} \times 9}{5} + 32 = x° \text{ F.} \qquad \frac{a° \text{ C.} \times 4}{5} = x° \text{ R.}$$

$$\frac{x^\circ \text{ R.} \times 9}{4} + 32 = x^\circ \text{ F.} \qquad \frac{a^\circ \text{ R.} \times 5}{4} = x^\circ \text{ C.}$$

Thus, to find what temperature Centigrade is equal to 113° F.

$$\frac{(113^\circ \text{ F.} - 32) \times 5}{9} = 45^\circ \text{ C.}$$

And to convert − 32° R. into Fahrenheit's scale,

$$\frac{-32^\circ \text{ R} \times 9}{4} + 32 = -40^\circ \text{ F.}$$

It is frequently convenient to express temperatures on the "absolute scale" in which the degrees are equal to those on the Centigrade scale, but the zero point is 273° below the melting-point of ice.

Hence any temperature on the Centigrade scale is converted into the absolute scale by adding 273° to it.

Thus −13° C. is −13° + 273° = 260° on the absolute scale.

(6.) Expansion by Heat.

Gay Lussac's Law.—273 volumes of gas at 0° C. increase by one volume for every 1° C. through which they are heated.

Thus: 273 volumes of gas at 0° C. become at 1° C. 273 + 1 volumes.
273 ,, ,, ,, ,, 2° C. 273 + 2 ,,
273 ,, ,, ,, ,, 3° C. 273 + 3 ,,
273 ,, ,, ,, ,, t° C. 273 + t ,,
273 ,, ,, ,, ,, T° C. 273 + T ,,

where t and T express any number of degrees on the Centigrade scale.

Hence 273 + t volumes of gas at t° C. become at T° C. 273 + T volumes.

or 1 ,, ,, t° C. ,, T° C. $\frac{273+T}{273+t}$,,

and v ,, ,, t° C. ,, T° C. $v \times \frac{273+T}{273+t}$,,

which, if V stand for the new volume of the gas after the temperature has changed from t° C. to T° C., is written

$$V = \frac{v\,(273 + T)}{273 + t}.$$

Thus to find the new volume if 1000 ccm. of gas are heated from 17° C. to 27° C.

$$V = \frac{1000\,(273 + 27)}{273 + 17} = \frac{1000 \times 300}{290} = 1034{\cdot}8 \text{ ccm.}$$

And to find the new volume if 1000 ccm. of gas are cooled from 27° C. to − 13° C.

$$V = \frac{1000\,(273 - 13)}{273 + 27} = \frac{1000 \times 260}{300} = 866{\cdot}6 \text{ ccm.}$$

If the pressure on the gas as well as its temperature be changed the formula must be combined with the one given in (4). Hence

$$V = \frac{v\,(273 + T)}{273 + t} \times \frac{p}{P}.$$

Thus to find the new volume if 500 ccm. of gas are cooled from 39° C. to 13° C. while the pressure is decreased from 800 mm. to 300 mm.

$$V = \frac{500\,(273 + 13)}{273 + 39} \times \frac{800}{300} = \frac{500 \times 286 \times 800}{312 \times 300} = 1222{\cdot}2 \text{ ccm.}$$

The above law may also be expressed more briefly :—The volume of a mass of gas varies directly as its absolute temperature. If a mass of gas have the volumes V and v at $T°$ C and $t°$ C.

$$V : v :: (273 + T)° : (273 + t)°.$$

It is more exact and frequently, especially when logarithms are used, more convenient to use the decimal fraction ·00367 instead of $\frac{1}{273}$ for the co-efficient of expansion (α) of a gas. Then

$$V = \frac{v\,(1 + {\cdot}00367\,T)}{1 + {\cdot}00367\,t}. \qquad \text{(Table VI.)}$$

Solids and liquids also expand when heated, but so slightly that in ordinary chemical experiments the expansion may be neglected. The formulæ are similar to those given for gases, but each solid or liquid has its own "coefficient of expansion."

Thus 5550 volumes of mercury at 0° C. increase by one volume for each degree through which they are heated, or become 5550 + 100 volumes at 100° C.

(7.) Formula, Molecular Weight, and Percentage Composition.

The atomic weight of an element is the number of times which the smallest portion of that element, which can take part in a chemical change, is heavier than the smallest portion of hydrogen which can take part in a chemical change.

An atom of hydrogen is supposed to weigh $3{\cdot}5 \times 10^{-24}$ gm.

The atomic weights are expressed by symbols, which are usually the first letter or two letters of the English or Latin name of the element.

Thus H represents the hydrogen-atom weighing 1.
O ,, oxygen-atom ,, 16.
Fe ,, iron-atom ,, 56 (Table I.)

The molecular weight of an element or compound is the number of times which the smallest portion of that element or compound, which can exist by itself or the free state, is heavier than the atom of hydrogen.

Comparatively few of the molecular weights of the elements have as yet been determined, they are usually twice the atomic weights.

Thus $H_2 = 1 \times 2 = 2$ is the molecular weight of hydrogen.
$O_2 = 16 \times 2 = 32$,, ,, oxygen.
$N_2 = 14 \times 2 = 28$,, ,, nitrogen.

But the molecular weights of mercury and cadmium are equal to their atomic weights, while those of phosphorus and arsenic are four times their atomic weights.

The molecular weight of a compound is the *sum* of the atomic weights of all the atoms which compose it. Thus the molecular weight of hydrogen chloride HCl is $1 + 35{\cdot}5 = 36{\cdot}5$; of water H_2O is $(1 \times 2) + 16 = 18$: of hydrogen sulphate H_2SO_4 is $(1 \times 2) + 32 + (16 \times 4) = 98$.

Since the formula expresses the proportion of each element present in the molecular weight of a body, it is easy to calculate from it the percentage composition, or number of grams of each element present in 100 gm. of a compound.

Thus H_2O means that in 18 gm. of water there are 2 gm. of hydrogen and 16 gm. of oxygen.

$\therefore$ in 1 gm. of water there are $\frac{2}{18}$ gm. of hydrogen and $\frac{16}{18}$ gm. of oxygen.

or in 100 gm. ,, ,, $\frac{200}{18}$,, ,, $\frac{1600}{18}$,, ,,

or the percentage composition of water is hydrogen $11{\cdot}1\%$.
oxygen $88{\cdot}8\%$.

Hence to find the percentage composition of any substance from its formula, multiply the proportion of each element present by 100, and divide by the molecular weight of the compound. If water be present it is usual to treat it as though it were an element (Aq = 18) and not to break it up into oxygen and hydrogen.

Thus to find the percentage composition of crystallised ferrous sulphate $FeSO_4.7H_2O$.

$$Fe = 56 \times \frac{100}{278} = \frac{5600}{278} = 20{\cdot}14\%.$$

$$S = 32 \times \,,, = \frac{3200}{278} = 11{\cdot}51\%.$$

$$4O = 64 \times \,,, = \frac{6400}{278} = 23{\cdot}02\%.$$

$$7H_2O = \frac{126}{278} \times \,,, = \frac{12600}{278} = 45{\cdot}32\%.$$

$$99{\cdot}99$$

(8.) The Density of Gases.

Since gases expand when heated and contract when the pressure is increased so considerably, in considering the mass of a volume of gas some standard temperature and pressure must be taken.

A gas is said to be *normal* when it is at 0° C. and under the pressure of 760 mm. of mercury. And as the formulæ given in this and the next two sections only apply to normal gases, a gas under any other conditions must be reduced by the equation

$$V = \frac{v \times 273}{273 + t} \times \frac{p}{760}$$ before they can be applied.

And conversely the volumes found by these formulæ are normal and must be reduced to the required temperature and pressure by

$$V = \frac{v(273 + T)}{273} \times \frac{760}{p}.$$

When no temperature or pressure is mentioned the gas is supposed to be normal.

The density of a substance is the mass of unit volume of it (1), but in the case of gases the cubic centimetre is too small a volume and the gram too large a mass for convenience.

Hence the litre is taken as the unit of volume and the mass of a litre of normal hydrogen called a *crith* = ·0896 gm. is taken as the unit of mass.

The density of a gas then is the number of criths contained in one litre of it at 0° C. and 760 mm.; or the number of times it is heavier than an equal volume of hydrogen.

It is found that with few exceptions the density of a gas is expressed by the same number as half its molecular weight :—

Hydrogen ($H_2 = 2$).	Density 1 ; or 1 l.	weighs 1 crith.	
Oxygen ($O_2 = 32$).	Density 16 ; or 1 l.	,, 16 criths.	
Nitrogen ($N_2 = 28$).	Density 14 ; or 1 l.	,, 14	,,
Ammonia ($NH_3 = 17$).	Density 8·5 ; or 1 l.	,, 8·5	,,
Marsh gas ($CH_4 = 16$).	Density 8 ; or 1 l.	,, 8	,,
Carbon dioxide ($CO_2 = 44$).	Density 22 ; or 1 l.	,, 22	,,

Hence from the molecular weight of a gas the mass of a litre of it in criths or grams can be found.

Thus a litre of carbon monoxide (CO) weighs $\frac{28}{2} = 14$ criths or

$$14 \times \cdot0896 = 1\cdot2544 \text{ grams.}$$

Again the double density of a gas is expressed by the same number as its molecular weight, hence the molecular weight can be calculated from the mass of a litre of a gas.

Thus if a litre of oxygen weighs 1·4293 gm. what is its molecular weight?

The density is the mass of a litre in criths $\frac{1\cdot4293}{\cdot0896}$, and the double density or molecular weight is $\frac{1\cdot4293}{\cdot0896} \times 2 = 31\cdot9$.

The density of gases used to be referred to air. In such a case to find the density referred to hydrogen multiply by 14·436 (the density of air referred to hydrogen).

Thus sulphur dioxide is 2·22 times as heavy as air, what is its density referred to hydrogen?

$$2\cdot22 \times 14\cdot436 = 32\cdot04$$ the density referred to hydrogen.

To find the mass of a litre of gas the density of which referred to air is given, multiply by 1·293 the mass in grams of a litre of air.

Thus carbon dioxide is 1·529 times as heavy as air, what does a litre of it weigh?

$$1\cdot529 \times 1\cdot293 = 1\cdot977 \text{ gm.}$$

Conversely to find the density referred to air from that referred to hydrogen, multiply by ·06926 the density of hydrogen referred to air.

Thus how many times is nitric oxide (NO = 30) heavier than air? The density referred to hydrogen is $\frac{30}{2} = 15$.

The density referred to air is $15 \times \cdot06926 = 1\cdot0389$.

Owing to the molecules breaking up by heat at temperatures but little above their boiling-points, about fifteen substances form

vapours having densities either half or two-thirds of the half-molecular weight. In a few other cases the density of the vapour is expressed by the same number as the molecular weight.

ANOMALOUS VAPOUR DENSITIES. (Hydrogen = 1.)

Mercury 100.	Nitric oxide 15.
Cadmium 56.	Nitrogen tetroxide 23.
Phosphorus 62.	Arsenic trioxide 198.
Arsenic 150	Mercurous chloride 118.
	Hydrogen sulphate 24·5.
	Ammonium chloride 13·4.
	Phosphorus pentachloride 52.
	Chlorine trioxide 29·7.
	Chlorine tetroxide 33·8.

(9.) THE DIFFUSION OF GASES.

GRAHAM'S LAW.—The volumes of two gases which diffuse in equal times under the same circumstances are inversely proportional to the square roots of their densities.

Or, when two gases diffuse for equal times under the same conditions, the volume of the one gas which diffuses multiplied by the square root of its density is equal to the volume of the other gas which diffuses multiplied by the square root of its density.

$$V\sqrt{D} = v\sqrt{d}.$$

If 4 l. of hydrogen and 1 l. of oxygen diffuse through the same apparatus in 10 minutes, what is the density of oxygen ?

$$1\sqrt{D} = 4\sqrt{1}$$
$$\therefore D = 16.$$

100 ccm. of oxygen ($d = 16$) diffuse through a certain apparatus in a certain time. What volume of hydrogen iodide ($D = 64$) will diffuse under similar conditions ?

$$V\sqrt{64} = 100\sqrt{16}$$
$$V = 100\frac{\sqrt{16}}{\sqrt{64}} = 100 \times \frac{4}{8} = 50 \text{ ccm.}$$

The law of effusion, or the passage of gases through a minute hole in a thin plate, is identical with that of diffusion.

(10.) The Volume and Mass of Gases.

It is found by experiment that 22·4 litres (more exactly $\frac{2}{\cdot 0896} = 22{\cdot}32$ l.) of any normal gas weigh a number of grams equal to the number expressing the molecular weight of the gas. Thus:—

22·4 l. of hydrogen ($H_2 = 2$) weigh 2 gm.
22·4 l. of oxygen ($O_2 = 32$) ,, 32 ,,
22·4 l. of ammonia ($NH_3 = 17$) ,, 17 ,,
22·4 l. of marsh gas ($CH_4 = 16$) ,, 16 ,,

This volume 22·4 l. is commonly spoken of as "two volumes," and expressed by the symbol □.

Since "two volumes" of any gas weigh the molecular weight in grams, one litre of any gas weighs the molecular weight in grams divided by 22·4 l., and one gram occupies 22·4 l. divided by the molecular weight in grams.

Thus a litre of oxygen weighs $\frac{32}{22{\cdot}4} = 1{\cdot}43$ gm.

and a gram of oxygen occupies $\frac{22{\cdot}4}{32} = 0{\cdot}7$ l.

Hence to find the mass in grams of any number of litres of a gas, multiply by the molecular weight in grams and divide by 22·4 l.

Thus to find the mass of 250 l. of chlorine ($Cl_2 = 71$)

$$\frac{250 \times 71}{22{\cdot}4} = \frac{177500}{224} = 792{\cdot}4 \text{ gm.}$$

And to find the volume in litres of any number of grams of a gas, multiply by 22·4 l. and divide by the molecular weight in grams.

Thus to find the volume of 225 gm. of hydrogen sulphide ($H_2S = 34$)

$$\frac{225 \times 22{\cdot}4}{34} = \frac{5040}{34} = 148{\cdot}2 \text{ l.}$$

When necessary the corrections for pressure and temperature must be used.

What is the mass of 80 l. of oxygen ($O_2 = 32$) at 52° C. and 740 mm.?

$$\frac{80 \times 273}{273 + 52} \times \frac{740}{760} \times \frac{32}{22{\cdot}4} = \frac{8880}{95} = 93{\cdot}47 \text{ gm.}$$

What volume at 13° C. and 750 mm. is occupied by 14·2 gm. of chlorine ($Cl_2 = 71$)?

$$\frac{14{\cdot}2 \times 22{\cdot}4}{71} \times \frac{273 + 13}{273} \times \frac{760}{750} = \frac{1510{\cdot}08}{225} = 6{\cdot}71 \text{ l.}$$

The Mass of a Moist Gas.

When a gas saturated with the vapour of water is measured, the pressure found is due partly to the true pressure of the gas and partly to the pressure of the aqueous vapour. Hence to obtain the true pressure of the gas that due to the "tension of aqueous vapour" must be subtracted from the apparent pressure of the saturated gas. The tension of aqueous vapour (F) varies very rapidly with the temperature, and is given in Table IV.

If v litres of a gas, the density of which is d, saturated with aqueous vapour be measured off at $t°$ C. and H mm. pressure, the true volume of the gas is $\frac{v}{1 + {\cdot}00367t} \times \frac{H - F}{760}$, and therefore its mass is $\frac{v}{1 + {\cdot}00367t} \times \frac{H - F}{760} \times {\cdot}0896 \times d$ grams, where F is the tension of aqueous vapour at the temperature $t°$ C.; and the mass of the aqueous vapour present in the gas is

$$\frac{v}{1{\cdot}00367t} \times \frac{F}{760} \times 0{\cdot}806 \text{ gm.}$$

Thus to find the mass of nitrogen and of aqueous vapour in 200 ccm. of moist nitrogen at 15° C. and 730 mm. ($F = 12{\cdot}7$).

$$\frac{{\cdot}2}{1 + {\cdot}00367 \times 15} \times \frac{730 - 12{\cdot}7}{760} \times 0{\cdot}0896 \times 14 = 0{\cdot}2246 \text{ gm. nitrogen.}$$

$$\frac{{\cdot}2}{1 + {\cdot}00367 \times 15} \times \frac{12{\cdot}7}{760} \times 0{\cdot}806 = 0{\cdot}00255 \text{ gm. aqueous vapour.}$$

Since the density of aqueous vapour is nearly $\frac{5}{8}$ of the density of air the mass of a litre of air saturated with aqueous vapour at $t°$ C. and H mm. is

$$\frac{1{\cdot}293}{1 + {\cdot}00367t} \times \frac{H - \frac{3}{8}F}{760} \text{ gm.}$$

(11.) Equations.

A chemical equation expresses that certain substances react upon one another in definite proportions to form certain other substances also in definite proportions.

Thus $Mg + O = MgO$ expresses that 24·4 parts of magnesium unite with 16 parts of oxygen to form 24·4 + 16 or 40·4 parts of magnesium oxide.

And if it be required to find how many grams of magnesium oxide are formed on burning 4 gm. of magnesium, from the equation :—

24·4 gm. of magnesium form 40·4 gm. of magnesium oxide.

$\therefore$ 1 gm. ,, forms $\frac{40·4}{24·4}$ gm. ,, ,,

and 4 gm. ,, form $\frac{4 \times 40·4}{24·4} = 6·62$ gm. of magnesium oxide.

How much magnesium must be burnt to form 16 gm. of magnesium oxide ?

40 gm. of magnesium oxide are formed by 24·4 gm. of magnesium.

1 gm. ,, ,, is ,, $\frac{24·4}{40·4}$ gm. ,,

16 gm. ,, ,, are ,, $\frac{24·4 \times 16}{40·4} = 9·66$ gm. of magnesium.

When the volume of one gas is given and that of another asked, since each molecular weight in grams expresses also "two volumes" of the normal gas the answer may be obtained directly.

Thus what volume of hydrogen chloride is formed when 10 l. of chlorine combine with hydrogen ?

$$\begin{array}{ccccc} Cl_2 & + & H_2 & = & 2HCl. \\ \square\!\square & & \square\!\square & & 2\,\square\!\square \end{array}$$

Two volumes of chlorine form twice two volumes of hydrogen chloride, hence 10 litres of chlorine form twice 10 litres or 20 l. of hydrogen chloride.

The requisite reductions must of course be made for change of temperature and pressure.

Thus, what volume of steam at 300° C. is formed on burning 10 l. of hydrogen at 15° C. ?

$$\underset{2\,\square\square}{2H_2} + \underset{\square\square}{O_2} = \underset{2\,\square\square}{2H_2O}.$$

Twice two volumes of hydrogen form twice two volumes of steam, hence 10 litres of hydrogen at 15° C. form $10 \times \frac{273 + 300}{273 + 15}$ l. of steam at 300° C. or $\frac{5730}{288} = 19{\cdot}895$ l. of steam.

When however the mass of a solid or liquid is given or asked and the volume of a gas is asked or given, the equation can only be solved by finding the mass of the gas.

Thus, how much lead sulphide can be precipitated by 17 l. of hydrogen sulphide? $\underset{34}{H_2S} + Pb2NO_3 = 2HNO_3 + \underset{239}{PbS}$.

17 l. of hydrogen sulphide weigh $\frac{17 \times 34}{22{\cdot}4}$ gm.

From the equation

34 gm. of hydrogen sulphide precipitate 239 gm of lead sulphide.

1 gm. ,, ,, ,, $\frac{239}{34}$,, ,, ,,

$\frac{17 \times 34}{22{\cdot}4}$ gm. ,, ,, ,, $\frac{17 \times 34}{22{\cdot}4} \times \frac{239}{34}$ gm. ,,

$\therefore$ 17 l. of hydrogen sulphide precipitate $\frac{17 \times 239}{22{\cdot}4} = 181{\cdot}3$ gm. of lead sulphide.

The required reductions must of course be made for pressure and temperature.

Thus, what volume of carbon dioxide at 39° C. and 380 mm. is formed on burning 10 gm. of carbon? $\underset{12}{C} + O_2 = \underset{44.}{CO_2}$.

12 gm. of carbon form 44 gm. of carbon dioxide.

1 gm. ,, forms $\frac{44}{12}$ gm. ,, ,,

10 gm. ,, form $\frac{10 \times 44}{12}$ gm. ,, ,,

10 gm. ,, ,, $\frac{10 \times 44}{12} \times \frac{22{\cdot}4}{44}$ l. of carbon dioxide at 0° C. and 760 mm.

10 gm. ,, ,, $\frac{10 \times 44}{12} \times \frac{22{\cdot}4}{44} \times \frac{273 + 39}{273} \times \frac{760}{380} = 42{\cdot}6$ l. of carbon dioxide at 39° C. and 380 mm.

Equations may be more shortly solved by proportion :—

The proportion of the given substance in the equation : the proportion of the required substance in the equation :: the amount of the substance given : the amount of the substance asked.

This method is of special use in certain determinations of molecular weights, since by a well-known formula if

$$a : b :: c : d \qquad a \pm b : b :: c \pm d : d.$$

Thus if 166·4241 gm. of ferric oxide when heated in hydrogen leave 116·5 gm. of iron, what is the atomic weight of the metal ?

$$\begin{array}{rl} & Fe_2O_3 + 6H = 3H_2O + 2Fe \\ 2x + 48 & \qquad\qquad\qquad\quad 2x \\ 2x + 48 : 2x :: & 166{\cdot}4241 : 116{\cdot}5 \\ 48 : 2x :: & 49{\cdot}9241 : 116{\cdot}5 \end{array}$$

$$x = \frac{48 \times 116{\cdot}5}{2 \times 49{\cdot}9241} = 56.$$

(12.) Vapour Density.

The methods of determining the density of vapours are very numerous, but for purposes of calculation they may all be divided into two classes :

(i.) In the methods of Gay Lussac, Hofmann, Meyer, and others, a known mass of the substance is converted into vapour, the volume of which is measured.

(ii.) In the methods of Dumas, Deville and Troost, and others, the vapour of the substance is caused to fill a vessel of known size and mass, and the mass of the vessel and substance, the vapour of which filled it, is afterwards determined.

(*a*) Hofmann's Method.—An amount of the substance weighing M grams is passed up into a long graduated tube containing mercury, and surrounded by a jacket of vapour, which raises it to $T°$ C. The volume of the vapour in the tube V ccm., the height of the barometer H mm. reduced, and the height of the mercury in the tube h mm. at $T°$ C. are measured.

The volume of the tube becomes at $T°$ C. $V(1 + \cdot00003\ T)$, the height of the mercury at 0° C. is $\frac{h}{1 + \cdot00018\ T}$ and the tension of the vapour of mercury at $T°$ C. is f mm.

Water b.p. 100° C.	$f = 0{\cdot}3$ mm.
Amyl alcohol b.p. 132° C.	$f = 1{\cdot}2$ mm.
Aniline b.p. 183·7° C.	$f = 9$ mm.
At 200° C.	$f = 18$ mm.

Hence the mass of a volume of hydrogen equal to that of the vapour is

$$\frac{V(1 + \cdot00003\ T)}{1 + \cdot00367\ T} \times \frac{H - f - h(1 - \cdot00018\ T)}{760} \times \cdot0000896 \text{ gm.}$$

And the density of the vapour, which is its mass divided by the mass of an equal volume of hydrogen, is

$$D = \frac{M(1 + \cdot00367\ T) \times 760}{V(1 + \cdot00003\ T)[H - f - h(1 - \cdot00018\ T)] \times \cdot0000896}$$

The vapour of ethyl-propinyl ($C_3H_8O = 84$) gave the following numbers:—$M = 0{\cdot}0518$ gm. $V = 52{\cdot}5$ ccm. $T = 100°$ C. $H = 752{\cdot}5$ mm. $h = 484$ mm.

$$\therefore D = \frac{\cdot0518\ (1{\cdot}367) \times 760}{52{\cdot}5\ (1{\cdot}003)\ [752{\cdot}5 - 476] \times \cdot0000896} = 41{\cdot}2.$$

(β) V. AND C. MEYER'S METHOD.—A quantity of the substance weighing M gm. is dropped into a heated vessel and the displaced air or nitrogen is found to measure V ccm. *over water* at $T°$ C. and H mm. Whatever the temperature of the vessel the volume of air collected is equal to what the vapour would measure at $T°$ C. and H mm.

Hence if F be the tension of aqueous vapour at $T°$ C. the mass of a volume of hydrogen equal to the volume of the vapour is

$$\frac{V}{1 + \cdot00367\ T} \times \frac{H - F}{760} \times \cdot0000896 \text{ and}$$

$$D = \frac{M(1 + \cdot00367\ T)\ 760}{V(H - F) \times \cdot0000896}$$

A sample of lutidine ($C_7H_9N = 107$) gave the following numbers:—$M = 0{\cdot}0894$ gm. $V = 20$ ccm. $H = 761{\cdot}5$ mm. $T = 12°$ C.

$$\therefore D = \frac{\cdot0894\ (1 + \cdot00367 \times 12)\ 760}{20 \times (761{\cdot}5 - 10{\cdot}5) \times \cdot0000896} = 52{\cdot}7.$$

(γ) DUMAS' METHOD.—A glass globe, weighing w gm., and containing a few grams of the substance is heated in a bath until no more vapour issues; it is then sealed at $T°$ C. and H_1 mm.

It is cleaned, cooled, and found to weigh W gm. at $t_1°$ C. and H_2 mm. The globe is opened under mercury, and its volume V ccm. at 0° C. found by measurement and calculation. If the mercury does not entirely fill the globe the volume v ccm. of the residual air is determined at $t_2°$ C. and H_3 mm. Neglecting the volume of air displaced by the glass, the mass of the substance is $W - w +$

the mass of a volume of air at $t_1°$ C. and H_2 mm. equal to the volume of the globe :—

$$W - w + \frac{V(1 + \cdot00003t_1) \times H_2 \times \cdot001293}{(1 + \cdot00367\,t_1) \times 760} \text{ gm.}$$

And the mass of a volume of hydrogen equal to and under the same conditions as the vapour when the globe is sealed is

$$\frac{V(1 + \cdot00003\,T) \times H_1 \times \cdot0000896}{(1 + \cdot00367\,T) \times 760} \text{ gm.}$$

$$\therefore D = \frac{W - w + \dfrac{V(1 + \cdot00003\,t_1) \times H_2 \times \cdot001293}{(1 + \cdot00367\,t_1) \times 760}}{\dfrac{V(1 + \cdot00003\,T) \times H_1 \times \cdot0000896}{1 + \cdot00367\,T) \times 760}}$$

The presence of residual air must be avoided as far as possible, since it is apt to render the experiment untrustworthy. The mass of the residual air renders the mass of vapour found above too great, and hence it must be subtracted from the numerator of the fraction, it is :—

$$\frac{v \times H_2 \times \cdot001293}{(1 + \cdot00367\,t_2) \times 760} \text{ gm.}$$

The volume occupied by the vapour, and therefore the volume of the hydrogen has been taken too large by the volume of the residual air at the moment of sealing the globe. Hence the mass of this volume of hydrogen must be subtracted from the denominator of the fraction, it is :—

$$\frac{V \times H_2 \times \cdot0000896}{(1 + \cdot00367\,t_2) \times 760} \text{ gm.}$$

And the complete formula becomes :—

$$D = \frac{W - w + \dfrac{\cdot001293}{760}\left\{\dfrac{V(1 + \cdot00003\,t_1)H_2}{1 + \cdot000367\,t_1} - \dfrac{v \times H_2}{1 + \cdot000367\,t_2}\right\}}{\dfrac{\cdot0000896}{760}\left\{\dfrac{V(1 + \cdot00003\,T)H_1}{1 + \cdot00367\,T} - \dfrac{v \times H_2}{1 + \cdot00367\,t_2}\right\}}$$

If great accuracy is not required this formula may be much simplified by neglecting the expansion of glass, making $t_1 = t_2$, and $H_1 = H_2 = H_3$. The formula then becomes :—

$$D = \frac{W - w + \cdot000001702\,H\left(\dfrac{V - v}{1 + \cdot00367\,t}\right)}{\cdot000000118\,H\left(\dfrac{V}{1 + \cdot00367\,T} - \dfrac{v}{1 + \cdot0367\,t}\right)}$$

Thus the following results were obtained for alcohol ($C_2H_6O = 46$). Mass of globe $w = 76{\cdot}9174$ gm. Mass of globe and vapour sealed at 100° C. $W = 77{\cdot}047$ gm. Volume of the globe $V = 449{\cdot}32$ ccm. Volume of residual air $v = 3{\cdot}277$ ccm. Temp. of room $t = 14°$ C. Barometer $H = 739$ mm.

$$\therefore D = \frac{77{\cdot}047 - 76{\cdot}9174 + {\cdot}000001702 \times 739\left(\frac{449{\cdot}32 - 3{\cdot}277}{1 + {\cdot}00367 \times 14}\right)}{{\cdot}000000118 \times 739\left(\frac{449{\cdot}32}{1{\cdot}367} - \frac{3{\cdot}277}{1 + {\cdot}00367 \times 14}\right)} = 23{\cdot}35.$$

(13.) HEAT.

Heat is one of the forms in which energy shows itself, and probably consists in the relative motion of the particles of matter.

When heat is communicated to a body it may raise the temperature, increase, or in rare instances decrease the volume, change the state from solid to liquid, or from liquid to gas, or cause it to undergo chemical change.

The *unit of heat* or calorie is the amount of heat required to raise a kilogram of water from 0° C. to 1° C.

The *Specific Heat* of a substance is the number of units of heat required to raise a kilogram of it from 0° C. to 1° C.

The Specific Heats are in almost all cases less than 1.

DULONG AND PETIT'S LAW.—The specific heat of an element in the solid condition multiplied by its atomic weight is called the atomic heat of the element, and is approximately equal to 6·4.

Hence if 6·4 be divided by the specific heat of an element, a number nearly equal to its atomic weight is obtained.

Thus the specific heat of solid mercury (Hg = 200) is ·03192, and $\frac{6{\cdot}4}{{\cdot}03192} = 200{\cdot}5$.

Elements, except oxygen, carbon, hydrogen, boron, and silicon, when they have entered into combination appear to keep the same atomic heat, which they possessed in the free condition.

Thus for potassium chloride KCl $6{\cdot}4 + 6{\cdot}4 = 12{\cdot}8$
Specific heat ·17295 × 74·5 molecular weight = 13·2

When a solid liquefies it absorbs a large amount of *latent heat*, amounting in the case of ice to 79·25 units per kilo.; and when a liquid passes into the condition of a vapour, a still larger amount of latent heat amounting in the case of steam to 536 units per kilo. is absorbed.

When chemical action takes place heat is either evolved (exo-

thermic reactions) or absorbed (endothermic reactions) according as the substances resulting from the action are more or less stable than those which have entered into it.

The amount of heat evolved is usually expressed in calories, when the number of grams of each substance is equal to the proportion of that substance which enters into the reaction.

Thus $(H_2,O) = 69$ means that 2 gm. of hydrogen in uniting with 16 gm. of oxygen evolve 69 units of heat.

If heat is absorbed the amount is preceded by the sign $-$. Thus $(C_2,H_4) = -10{\cdot}8$ means that 24 gm. of carbon in uniting with 4 gm. of hydrogen absorb 10·8 units of heat.

If the reaction takes place in presence of an indeterminate quantity of water, Aq is added to the symbols.

Thus $(NH_3, Aq) = 8$ means that 17 gm. of ammonia, while dissolving in water give off 8 units of heat.

In many practical experiments the *calorific power* of a substance, or number of units of heat evolved when 1 kilo. of it is burnt in oxygen, is made use of.

(14.) The Determination of Equivalents.

The equivalent of an element or compound is the proportion of it, which can do the same amount of chemical work in combining with or replacing other elements or compounds as one part of hydrogen.

Equivalents are conveniently expressed by the same symbols as the atomic weights, but in small letters, *e.g.*, oxygen *o*.

The equivalent of an element is determined either by analysing a compound of it with an element or radical the equivalent of which is known, or by causing a known mass of it to combine with or replace another element or radical the equivalent of which is known.

The masses of the two substances which unite with or replace one another, are in the same proportion as the equivalents. Hence if the two masses and one equivalent are known, the other equivalent can be determined (**11**).

Thus to determine the equivalent of lead Berzelius found that 21·9425 gm. of lead oxide contain 20·3695 gm. of lead, and therefore $21{\cdot}9425 - 20{\cdot}3695 = 1{\cdot}573$ gm. of oxygen ($o = 8$).

Since 1·573 gm. of oxygen unite with 20·3695 gm. of lead.

8 ,, ,, ,, ,, $\dfrac{8 \times 20{\cdot}3695}{1{\cdot}573} = 103{\cdot}596$ gm. of lead.

Hence $pb = 103{\cdot}596$ is the equivalent of lead.

(15.) The Determination of Atomic Weights.

The atomic weight of an element is the number of times which the mass of the least portion of it that can take part in a chemical change is greater than the mass of the least portion of hydrogen which can take part in a chemical change. If the atomic theory be admitted, the atomic weight of an element is the number of times its atom is heavier than an atom of hydrogen.

Atomic weights are multiples of the equivalents by small (1 – 6) whole numbers. Which multiple is to be chosen is to be determined by considering in each reaction into which the element is known to enter, what is the smallest multiple of the equivalent which expresses the action. Special attention is paid to cases in which the element combines with monovalent elements or radicals.

Thus we know two bodies in which 103·596 parts of lead are combined with 35·5 parts of chlorine and 19 parts of fluorine respectively, and which may be expressed by *pb cl*, and *pb f*. But a third body is known in which 207·192 parts of lead are combined with 35·5 parts of chlorine and 19 parts of fluorine, which must be expressed by *pb cl pb f*, or more simply by Pb Cl F. where Pb = *pb pb* = 2 × 103·596 = 207·192.

Further assistance is rendered by the isometric law of Mitscherlich, "Bodies, which are composed of the same number of similar atoms arranged in a similar manner, crystallize in similar forms."

And also by the Law of Dulong and Petit (**13**).

Thus in the case of lead the choice has to be made between the multiples of 103·596 by 1, 2, 3, 4, &c., or 103·596, 207·192, 310·798, 414·384, &c. But the specific heat of lead is found to be ·0315 and $\frac{6\cdot4}{\cdot0315} = 203\cdot1$. Therefore Pb = 207·192 is the most probable atomic weight of lead.

There are somewhat numerous exceptions to both these laws, and new reactions are frequently found to modify the received atomic weight of an element. Hence in some cases the received atomic weights must be looked upon as only provisional.

(16.) The Determination of Molecular Weights.

The molecular weight of a body is the number of times which the mass of the smallest portion of it, which can exist by itself or in the free state, is heavier than the atom of hydrogen.

When a compound is analysed the results are usually calculated into percentages or parts of each element present in 100 parts of the compound. (Water if present is reckoned as an element Aq = 18). If the proportion of each element present be divided

by the atomic weight of that element, the quotients express the relative number of atoms of each element present in the compound. To accord with the atomic theory these relative numbers must be expressible by whole numbers, usually small. If simple inspection affords no clue, there are three methods of effecting this reduction :—

(i.) Divide each quotient by the smallest quotient, all then frequently become whole numbers or may be made so by multiplication by the same number.

Thus ferric oxide contains iron 70 per cent., oxygen 30 per cent. Find its formula.

$$\text{Fe}\ \frac{70}{56} = 1{\cdot}25 \qquad 1 \times 2 = 2$$

$$\text{O}\ \frac{30}{16} = 1{\cdot}875 \qquad 1{\cdot}5 \times 2 = 3$$

Fe_2O_3.

(ii.) Write instead of one quotient an easily divisible number, such as 6, 12, 28, 60, and alter the other quotients in the same proportion. Division by the highest common factor gives the small whole numbers required.

Thus to find the formula of crystallized ferrous sulphate, which contains iron 20·15, sulphur 11·51, oxygen 23·02, and water 44·31 per cent.

Fe	$\frac{20{\cdot}15}{56} = {\cdot}36 \times \frac{12}{1{\cdot}44}$	3	1	
S	$\frac{11{\cdot}51}{32} = {\cdot}36$,,	3	1	$FeSO_4 7H_2O$.
O	$\frac{23{\cdot}02}{16} = 1{\cdot}44$,,	12	4	
H_2O	$\frac{44{\cdot}31}{18} = 2{\cdot}46$,,	20·5	7	

(iii.) It occasionally happens that the ratio between the quotients is too complicated to be conveniently reduced by either of the foregoing methods. The continued fraction expressing the ratio between two of the quotients must be found, and that convergent selected which expresses the ratio in the lowest terms within the limits of experimental error.

Thus common sugar is found to contain :—

Carbon	42·11 ;	$\frac{42{\cdot}11}{12} = 3{\cdot}51$ atoms of carbon.
Hydrogen	6·43 ;	6·43 atoms of hydrogen.
Oxygen	51·46 ;	$\frac{51{\cdot}46}{16} = 3{\cdot}215$ atoms of oxygen.

Since the number of atoms of hydrogen is double of the number of atoms of oxygen, the only ratio which has to be determined is that of carbon to oxygen, which is $\frac{3{\cdot}51}{3{\cdot}215} = \frac{702}{648}$

643)702(1
643

59)643(10
590

53)59(1
53

6)53(8
48

5)6(1

Hence the quotients are 1, 10, 1, 8, 1,

and the convergents $\frac{1}{1'}$ $\frac{11}{10'}$ $\frac{12}{11'}$ $\frac{107}{98}$.

Hence the ratio between the carbon and oxygen atoms is probably expressed by $\frac{12}{11}$, and the formula of cane-sugar is $C_{12}H_{22}O_{11}$.

There are five general methods of determining which multiple of the symbol obtained as above is to be taken as representing the true molecular weight of the body, but in many cases neither is applicable.

(i.) By the Vapour Density :—If the body can be volatilized without decomposition, the vapour-density is found by one of the methods given in (12) and with some exceptions such as those mentioned in (8) it is assumed that the molecular weight is expressed by the same number as the double-density referred to hydrogen.

Thus cuprous chloride contains 63·3 pts. of copper united with 35·5 pts. of chlorine, and its molecular weight is therefore expressed by CuCl = 98·8 or by some multiple of this number.

But the vapour of cuprous chloride is found to be 6·93 times as heavy as air or its double-density is 200·08 and hence its symbol probably is Cu_2Cl_2 = 197·6.

(ii.) The Chemical Method :—Various compounds or substitution products of the body are analysed—if it be an acid, its silver salt ; if it be a base, the nitrate, chloride, or bromide ; if it be an organic body its chloro- or bromo-substitution compound, and that formula is adopted which most readily expresses the mode of formation and constitution of these compounds.

Thus hydrogen acetate is found to contain :—

Carbon	40	$\frac{40}{12}$	= 3·3	1
Hydrogen	6·6		= 6·6	2
Oxygen	53·4	$\frac{53·4}{16}$	= 3·3	1

and its composition is expressed by CH_2O or by some multiple of this symbol.

When sodium acetate is mixed with silver nitrate, silver acetate is formed, which is found to contain :—

Carbon	14·37	$\frac{14·37}{12}$	= 1·2 ?	2
Hydrogen	1·79		= 1·8 ?	3
Silver	64·68	$\frac{64·68}{108}$	= ·6 ?	1
Oxygen	19·16	$\frac{19·16}{16}$	= 1·2 ?	2

Hence the most simple formula for silver acetate is $AgC_2H_3O_2$.

Again by the action of chlorine on hydrogen acetate, three chloro-substitution acids are formed, of which hydrogen trichloracetate is found to contain :—

Carbon	14·68	$\frac{14·68}{12}$	= 1·22	2
Hydrogen	·61		= ·61	1
Chlorine	65·14	$\frac{64·14}{35·5}$	= 1·83	3
Oxygen	19·57	$\frac{19·57}{16}$	= 1·22	2

Hence the most simple formula for hydrogen trichloracetate is $C_2HCl_3O_2$; and by similar methods the formulæ $C_2H_3ClO_2$, $C_2H_2Cl_2O_2$ are found for the other two acids.

Since the hydrogen in the original hydrogen acetate can thus be replaced by fourths, there must be at least four atoms of hydrogen in the symbol which probably is $C_2H_4O_2$.

The reactions mentioned above are then expressed by :—

$$NaC_2H_3O_2 + AgNO_3 = NaNO_3 + AgC_2H_3O_2.$$
$$C_2H_4O_2 + 3Cl_2 = 3HCl + C_2HCl_3O_2.$$

The last three methods depend upon the change produced in the physical properties of a liquid when a small proportion of a solid or more stable liquid is dissolved in it. The freezing point of the solution is lower than that of the solvent, at the same temperature the vapour pressure of the solution is lower than that of the solvent; at the same pressure the boiling-point of the solution is higher than that of the solvent.

These methods are not applicable to electrolytes, such as salts dissolved in water, since the results are lower than those accepted on chemical grounds, possibly owing to the dissociation of the molecules into ions.

(iii.) From the freezing-point:—If the solution of w gm. of a substance in 100 gm. of a liquid is found to lower the freezing-point $F°$, $m = Kw/F$, where m is the molecular weight and K a constant for each liquid.

The solution of a gram of nitrobenzene ($C_6H_5NO_2 = 123$) in 100 gm. of benzene ($K = 50$) was found to lower the freezing-point by 0·4° C.

$$m = 50/0{\cdot}4 = 125.$$

(iv.) From the vapour-pressure:—The difference between the vapour pressure of a solvent (p_1) and that of a dilute solution (p_2) is to the vapour pressure of the solvent at the same temperature as the relative number of molecules of the substance present (n) is to the relative number of molecules of the solution ($N + n$). If w ($= mn$) be the number of grams of the substance dissolved in a gram molecule of the solvent $N = 1$ and

$$\frac{p_1 - p_2}{p_1} = \frac{n}{N + n} = \frac{w}{m + w} \text{ or } m = \frac{wp_2}{p_1 - p_2}.$$

Owing to the difficulty of determining the vapour pressure, the following indirect method is used in practice. If a current of dry air be led through a bulb containing the solution, and then through a bulb containing the solvent at the same temperature, the loss of weight of the first bulb (W_2) is proportional to the vapour pressure of the solution, and the loss of weight of the second bulb (W_1) is proportional to the difference between the vapour pressures of the solvent and of the solution, so that $m = wW_2/W_1$.

A solution of 7·74 gm. of aniline ($C_6H_7N = 93$) in 100 gm. of ether ($C_4H_{10}O = 74$) during the passage of a current of dry air lost 1·4785 gm. while the ether lost 0·0969 gm. The weight of aniline in the gram-molecule of ether being $7{\cdot}74 \times 74/100 = 5{\cdot}7276$,

$$m = 5{\cdot}7276 \times 1{\cdot}4785/0{\cdot}0969 = 87{\cdot}4.$$

(v.) From the boiling-point:—If the solution of w gm. of a substance in 100 gm. of a liquid is found to raise the boiling-point $b°$, $m = kw/b$, where k is a constant for each solvent.

1·942 gm. of pyrogallol ($C_6H_6O_3 = 126$) dissolved in 100 gm. of ether ($k = 21·1$) raised the boiling-point 0·315°. Hence

$$m = 21·1 \times 1·942/0·315 = 130.$$

In approximate work it is more convenient to measure than to weigh the solution, making use of the volume constant κ instead of the weight constant k. Then $m = \kappa w/b$.

0·835 gm. of mercuric chloride ($HgCl_2 = 271$) dissolved in alcohol raised the boiling-point 0·32° C. Since the volume of the solution was 15·6 ccm. the weight of salt in 100 ccm. was $0·835 \times 100/15·6 = 5·35$ gm. Hence

$$m = 15·6 \times 5·35/0·32 = 261.$$

K, k, or κ may be found for any solvent by an experiment with a substance of known molecular weight. K may be found by dividing twice the square of the absolute temperature of the freezing-point by one hundred times the latent heat of liquefaction; k may be found by dividing twice the square of the absolute temperature of the boiling-point by one hundred times the latent heat of vaporization; κ may be found by dividing k by the density at the boiling-point.

	K	k	κ
Water	18·5	5·2	5·4
Hydrogen acetate . . .	89	25·3	
Benzene	50	26·7	32·8
Carbon disulphide . . .		23·7	
Chloroform		36·6	26
Alcohol		11·5	15·6
Ether		21·1	30·3
Acetone		16·7	22·2

The determination of the molecular weights of the elements is a matter of very great difficulty, and it seems probable that in some cases, *e.g.* oxygen, sulphur, chlorine, an element may have more than one molecular weight under different conditions.

The vapour densities of the ten elements, hydrogen, oxygen, nitrogen, chlorine (below 800° C.), bromine, iodine, sulphur (above 1000° C.), selenium, tellurium, and potassium are found to be expressed by the same numbers as their atomic weights. Hence their double-densities, and probably their molecular weights, are equal to twice their atomic weights.

The density of the vapours of mercury and cadmium is found to be only half of their atomic weights. Hence their molecular and atomic weights are probably equal. Argon, helium, and crypton seem to show the same peculiarity.

The density of the vapours of phosphorus and arsenic is found to be twice their atomic weights. Hence their molecules probably consist of four atoms.

(17.) The Formulæ of Minerals.

In determining the formulæ of minerals numerous difficulties are met with which do not occur in ordinary determinations of molecular weights. No help can be obtained from vapour-density determinations, and only in rare cases can any compound of the mineral be formed. The body analysed is frequently far from pure, and similar elements, such as calcium and ferrous iron, may replace one another in any proportion; this is expressed in symbols by [CaFe]. The composition, especially when silica, alumina, and water are present together, is often extremely complicated, since part of the alumina may perform basic and part acid functions.

Silicates used to be classified by mineralogists according to their "oxygen-ratio," that is, by the ratio between the number of atoms of oxygen supposed to be in combination with the metals, and the number of atoms of oxygen supposed to be in combination with silicon. Thus calcium metasilicate is found native as Wollastonite, the formula of which may be written as $CaO.SiO_2$, the oxygen ratio being 1 : 2. In Diopside more or less of the calcium is replaced by magnesium, and the formula is written $[CaMg]O.SiO_2$.

It is however now usual to bring mineralogical formulæ more into accordance with chemical theory by discarding the term oxygen ratio and replacing it by "quantivalent ratio," which is intended to represent the ratio of the quantivalences of the basic elements present to the quantivalence of the silicon. Thus Wollastonite is now regarded as dyad calcium united by two atoms of oxygen to tetrad silicon, two atomicities of which are also satisfied by oxygen

$$Ca\overset{ii}{O_2}Si\overset{iv}{O},$$

and the quantivalent ratio is 2 : 4.

The great majority of, if not all, the silicates may be regarded from a chemical point of view as salts derived from different silicic acids by the replacement of some or all of the hydrogen by metals. These silicic acids are all formed from one or more molecules of hydrogen orthosilicate combined together with the loss of a certain number of molecules of water. The general formula is $(H_4SiO_4)_m - (H_2O)_n = H_{2(2m-n)}Si_mO_{(4m-n)}$ where m and n may be any small whole numbers, m being always greater than or equal to n.

Thus if $m = 3$, $n = 0$, and in $H_{12}Si_3O_{12}$ six atoms of hydrogen are replaced by 3 atoms of calcium, and the other six by two atoms of ferric iron, the formula of garnet $Ca_3Fe_2Si_3O_{12}$ is obtained, which is expressed on the "oxygen ratio" system as $(CaO)_3(Fe_2O_3)(SiO_2)_3$, 1:1:2, and on the "quantivalent ratio" system as $Ca_3^{vi}\,Fe_2^{vi}\,\|O_{12}\|Si_3^{xii}$.

Again if $m = 6$ and $n = 6$, the formula $H_{12}Si_6O_{18}$ is obtained, from which $Be_3Al_2Si_6O_{18}$ beryl is derived.

It is customary to calculate the results of the analysis of a mineral not into percentages of elements but into percentages of oxides, and in all subsequent calculations to treat the oxides just as if they were elements ($SiO_2 = 60{\cdot}4$. $CaO = 56$. $Al_2O_3 = 102$). The formulæ are then obtained by the process given in the last section.

Thus to find the formula of chrysocolla which contains :—

Cupric oxide	44·82	$\frac{44{\cdot}82}{79{\cdot}3}$	= ·565	1
Silica	34·83	$\frac{34{\cdot}83}{60{\cdot}4}$	= ·576	1
Water	20·35	$\frac{20{\cdot}35}{18}$	= 1·12	2

and the formula is $CuOSiO_2 2H_2O$.

If an oxide be present in small proportion it has probably replaced a certain quantity of a similar oxide, and must therefore be reduced and added to the proportion of that oxide present before the calculation can be proceeded with.

In the case of many silicates containing alumina theory seems to show that part of the alumina is basic and part acid ($Al_2O_3 + H_2O = 2HAlO_2$) in its function.

Thus a sample of Andalusite was found to contain :—

Silica	37·57	$\frac{37{\cdot}57}{60{\cdot}4}$ = ·622	·622	1

Alumina	59·88	$\frac{59·88}{102} = ·587$	·595	1
Ferric oxide	1·33	$\frac{1·33}{160} = ·008$		
Lime	0·61	$\frac{·61}{56} = ·011$	·015	
Magnesia	0·17	$\frac{·17}{40·4} = ·004$		

Hence neglecting the small proportions of lime and magnesia which by their presence as silicates probably raise the percentage of silica the formula of the mineral is $Al_2O_3.SiO_2$.

The true composition of Andalusite probably is a double silicate and aluminate of aluminium :—

$$2Al_2OSiO_2 = Al_2^{vi}\begin{cases}(SiO_3)_2\\(AlO_2)_2^{i}\end{cases}$$

(18.) The Solubility of Solids in Water.

When solids dissolve in water heat is absorbed by the solid in passing to the liquid condition. But if the substance combines with water before it dissolves, the heat evolved in the formation of the hydrate may supply, or more than supply, the quantity of heat required for the solution of the solid.

The volume of the solution is generally less than the volumes of the solid and of the water together, and its boiling-point is usually above 100° C.

The solubility of a solid at any temperature $t°$ C. is most conveniently expressed by the number of grams (x) of the solid, which 100 gm. of water will dissolve. It is easy to convert any other expression into this form :—

Thus if m gm. of a solid are contained in M gm. of the saturated solution,

$$M - m : m :: 100 : x$$

$$\therefore x = \frac{100m}{M - m}.$$

And if y gm. of water are required to dissolve 1 gm. of the solid,

$$x : 100 :: 1 : y$$

$$x = \frac{100}{y}.$$

And if n gm. of the salt are contained in 100 gm. of the solution,

$$100 - n : n :: 100 : x.$$

$$x = \frac{100n}{100-n}.$$

The solubility of the great majority of solids at any temperature $t°$ C. is expressed by an equation of the form

$$x = a + bt + ct^2 + dt^3.$$

in which a b c and d are constants depending upon the special substance under consideration. Thus Gay Lussac found that the solubility of potassium nitrate is expressed by

$$x = 13{\cdot}82 + 0{\cdot}574t + 0{\cdot}0172t^2 + 0{\cdot}0000036t^3.$$

From this equation it is easy to find how many grams of water at 100° C. are required to dissolve 10 gm. of potassium nitrate.

$$x = 13{\cdot}82 + 57{\cdot}4 + 172 + 3{\cdot}6 = 246{\cdot}82 \text{ gm.}$$

and $247{\cdot}82 : 100 :: 10 : y$

$$y = 4{\cdot}0516 \text{ gm. of water.}$$

In many cases the solubility of a salt increases directly as the temperature, c and d are then either really 0 or so small that they have not yet been determined. Thus in the case of crystallized magnesium sulphate, $x = 25{\cdot}8 + 0{\cdot}493t$.

The solubility of a few substances such as sodium sulphate increases up to a certain temperature and then decreases. This is probably due to the formation of hydrates at low temperatures ($Na_2SO_4 10H_2O$ between 18° and 33° C. and Na_2SO_4 above 34° C.), each of which obeys its own law of solubility.

A few substances such as calcium hydrate become less soluble as the temperature rises.

No numerical rules concerning the solubility of liquids have yet been obtained.

(19.) The Solubility of Gases in Water.

Gases are absorbed by water, when they do not act chemically upon it, in quantities depending upon three conditions :—

(i.) The nature of the gas. The volume of normal gas absorbed by one volume of water at 0° C. is spoken of as the co-efficient of absorption of the gas.

(ii.) The temperature. The volume of the gas absorbed usually decreases as the temperature increases and can be expressed for any temperature $t°$ C. by the empirical formula

$$V = a - bt + ct^2.$$

Thus one volume of water between 0° C. and 20° C. absorbs of

Hydrogen	$V = 0{\cdot}0193.$		
Nitrogen	$V = 0{\cdot}020346$	$- 0{\cdot}00053887t$	$+ 0{\cdot}0000111566t^2.$
Oxygen	$V = 0{\cdot}04114$	$- 0{\cdot}00109t$	$+ 0{\cdot}0000226t^2.$
Carbon dioxide	$V = 1{\cdot}7967$	$- 0{\cdot}07761t$	$+ 0{\cdot}0016424t^2.$
Oxygen and nitrogen from air	$V = 0{\cdot}02471$	$- 0{\cdot}0006525t$	$+ 0{\cdot}00001345t^2.$

(iii.) The pressure on the gas. The mass of gas absorbed varies directly as the pressure upon it; or equal volumes of the same gas are absorbed under all pressures. If two or more gases are mixed together the absorption of each constituent is proportioned to the pressure to which it is separately subjected.

Thus, what is the percentage composition of the gases absorbed when a large volume of air is shaken up with water at 0° C.?

100 volumes of air contain nearly 21 volumes of oxygen and 79 volumes of nitrogen. Hence the pressure on the oxygen is $\frac{21}{100}$ and on the nitrogen $\frac{79}{100}$ of the total pressure.

One volume of water then absorbs $\cdot04114 \times \frac{21}{100} = \frac{0{\cdot}86394}{100}$ vol. of oxygen and $\cdot020346 \times \frac{79}{100} = \frac{1{\cdot}60733}{100}$ vol. of nitrogen.

Hence the percentage composition of the air dissolved by water is:—

Oxygen	0·86394	34·9 per cent. by vol.
Nitrogen	1·60733	65·1 per cent. by vol.
	2·47127	100·0

EXAMPLES.

CHAPTER I.

English and Metric Measures.

(*See Tables II. III.*)

1. A circular filter-paper is 10 cm. across, what is the area of it?
2. A cistern is 2 m. long, 1·5 m. wide, and 1 m. deep. How many litres of water will it contain?
3. The cylinder of a steam-engine is 3 ft. in diameter and 5 ft. long. How many cubic feet of steam will it contain?
4. How many pounds Troy are there in a kilogram?
5. Sound travels 1130 ft. in a second. How many metres does it pass through per second?
6. It is 92,000,000 miles to the sun; how many kilometres is it?
7. Light travels 186,000 miles per second. How many kilometres per second is that?
8. How many cubic feet of gas are contained in a cylindrical gasometer 180 ft. across and 46 ft. high?
9. How many litres will a cylindrical gasometer 1 m. across and 1·5 m. high hold?
10. A nautical fathom is 6·087 ft. What is its value in metres?
11. The velocity of light is $3{\cdot}004 \times 10^8$ m. per second, and it takes 8 minutes 13 seconds to pass from the sun to the earth. How many miles is the sun distant from the earth?
12. The Pyramid of Geeza stood 481 ft. high upon a base 774 ft. square. Find the volume of it in cubic feet.

Volume, Mass, and Density.

13. A piece of iron was found to weigh 292·8 gm. in air and 255·3 gm. when immersed in water. What is the density of it?
14. What is the density of a cube of oak 9 mm. along each edge, which weighs 0·62 gm.?
15. A cylinder of mahogany 10·1 cm. high and 9·4 cm. across weighed 405·7 gm. Find the density of it.
16. A block of steel (Δ 7·8) is 10 cm. square and 1·8315 cm. thick. Find the mass of it in grams.
17. What is the mass of a cubic metre of hematite (Δ 5·25)?
18. Find the volume of 1000 gm. of sea-water (Δ 1·026).

19. A round dolomite (Δ 2·9) pillar 1 m. across and 10 m. high weighs how many kilograms?

20. Two liquids having the densities 1·3 and 0·7 respectively are mixed. The mixture has the density 0·9 and measures 3 litres. What volume of the heavier liquid was taken?

21. A specific gravity flask weighing 21 grams when filled with water weighed 74 gm. and when filled with hydrogen chloride 84·6 gm. What is the density of the acid?

22. Find the mass of a cubic metre of anthracite (Δ 1·4).

23. Find the mass of a glass (Δ 2·45) cylinder 2 decimetres high and 1 dm. across.

24. How many tons does a block of granite (Δ 2·7) 10 by 3 by 2 metres weigh?

25. The great pyramid (Δ 2·5) is 145 m. high and the side of its square base is 658·3 m. Find the mass of it in tonnes.

26. A Nicholson's hydrometer required 20 gm. or a crystal of galena and 5·2 gm. to sink it. When the galena was in the lower pan 7·2 gm. were required. Find the density of the galena.

27. If a glass ball weighing 7·7158 gm. 2 cm. in diameter just floats in a liquid; find the density of the liquid.

28. A quantity of silver when placed in one pan of an untrue balance appeared to weigh 5 gm. but when placed in the other pan 6 gm. What is the true mass of the silver?

29. A Nicholson's hydrometer required 13·19 gm. or a piece of rock-crystal on the upper pan and 9·77 gm., or the same piece of rock-crystal on the lower-pan and 11·07 gm. to sink it. Find the density of the crystal.

30. A glass ball counterpoised in air appeared to lose 5·6 gm. when plunged into water and 5·09 gm. when plunged into turpentine. A crystal of copper sulphate, which weighed 11·69 gm. in air, when plunged into turpentine appeared to lose 4·63 gm. Find the density of the turpentine and of the copper sulphate.

31. A counterpoised specific gravity bottle holds 1000 grains of water, and, after the introduction of 150 grains of sand, weighs 1096 grains. What is the specific gravity of sand?

32. When 1·719 gm. of powdered rock crystal had been introduced into a specific gravity bottle filled to the line with water, the bottle gained 0·66 gm. What is the density of rock-crystal?

33. What is the density of potassium dichromate, if 6·2138 gm. of it displace 2·0532 gm. of benzene (Δ 0·8885)?

34. A specific gravity flask held 25·03 gm. of water or 22·24 gm. of benzene. 4·8569 gm. of ammonium dichromate displaced 1·995 gm. of benzene. Find the density of the dichromate.

35. A Sprengel tube weighed when empty 12·6 gm., when filled with water 38·4 gm. and when filled with dilute hydrogen sulphate 42·6 gm. What was the density of the acid?

CHAPTER II.

MOLECULAR WEIGHTS.

(*See Sect.* **10.**)

1. Find the molecular weight of (i.) carbon monoxide CO ; (ii.) magnesia MgO ; (iii.) lime CaO ; (iv.) silica SiO_2 ; (v.) alumina Al_2O_3.

2. What is the percentage of oxygen in each of the above-mentioned bodies ?

3. Find the molecular weights of (i.) nitric oxide NO ; (ii.) sodium hydrate HNaO ; (iii.) ferric oxide Fe_2O_3 ; (iv.) chromium trioxide CrO_3 ; (v.) cadmium oxide CdO.

4. Find the molecular weights of (i.) antimony pentoxide Sb_2O_5 ; (ii.) silver arsenate Ag_3AsO_4 ; (iii.) barium sulphate $BaSO_4$; (iv.) lead nitrate $Pb2NO_3$; (v.) potassium phosphate K_3PO_4.

5. Find the molecular weights of (i.) zinc sulphate $ZnSO_47H_2O$; (ii.) cupric sulphate $CuSO_45H_2O$; (iii.) sodium sulphate $Na_2SO_410H_2O$; (iv.) nickel sulphate $NiSO_47H_2O$; (v.) manganous sulphate $MnSO_44H_2O$.

6. Find the molecular weights of (i.) alcohol C_2H_6O ; (ii.) ether $C_4H_{10}O$; (iii.) hydrogen acetate $C_2H_4O_2$; (iv.) hydrogen oxalate $C_2H_2O_42H_2O$; (v.) hydrogen tartrate $C_4H_6O_6$.

7. Find the molecular weights of (i.) glycerin $C_3H_8O_3$; (ii.) turpentine $C_{10}H_{16}$; (iii.) aniline C_6H_7N ; (iv.) hydrogen stearate $C_{18}H_{36}O_2$; (v.) cane-sugar $C_{12}H_{22}O_{11}$.

8. Find the molecular weights of (i.) potassium chlorate $KClO_3$; (ii.) borax $Na_2B_4O_710H_2O$; (iii.) strontium bromide $SrBr_26H_2O$; (iv.) barium carbonate $BaCO_3$; (v.) potassium dichromate $K_2Cr_2O_7$.

9. Find the molecular weights of (i.) potassium ferrocyanide $K_4FeC_6N_63H_2O$; (ii.) calcium fluosilicate, $CaSiF_6$; (iii.) sodium thiosulphate $Na_2S_2O_35H_2O$; (iv.) microcosmic salt $NaNH_4HPO_44H_2O$; (v.) sodium nitroprusside $Na_4Fe_2C_{10}N_{10}(NO)_24H_2O$.

10. Find the percentage composition of (i.) mercuric oxide HgO ; (ii.) potassium chlorate $KClO_3$; (iii.) manganese dioxide MnO_2.

11. What is the percentage composition of cupric sulphate $CuSO_45H_2O$?

12. Calculate the percentage composition of theine $C_8H_{10}N_4O_2$.

CHAPTER III.

TEMPERATURES.

(*See Sect.* **5.**)

1. Convert into the Centigrade scale :—(i.) 36° R., (ii.) 28° R., (iii.) 76° R., (iv.) 60° R., (v.) 52° R.

2. Convert into the Réaumur scale :—(i.) 90° C., (ii.) 15° C., (iii.) 20° C., (iv.) 55° C., (v.) 30° C.

3. Convert into the Fahrenheit scale :—(i.) 56° R., (ii.) 60·44° R., (iii.) 41·78° R., (iv.) −6·67° R., (v.) −25·3° R.

4. Convert into the Réaumur scale :—(i.) 48° F., (ii.) 129° F., (iii.) 168° F., (iv.) 210° F., (v.) −30° F.

5. Convert into the Fahrenheit scale :—(i.) 60·5° C., (ii.) 40° C., (iii.) 70° C., (iv.) −5° C., (v.) −36·6° C.

6. Convert into the Centigrade scale :—(i.) 207° F., (ii.) 180° F., (iii.) 114° F., (iv.) 0° F., (v.) −30° F.

7. Convert into the Fahrenheit scale :—(i.) 643° C., (ii.) 720° C., (iii.) 860° C., (iv.) 973° C., (v.) 1000° C.

8. Convert into the Centigrade scale :—(i.) 674° F., (ii.) 100° F., (iii.) 463° F., (iv.) 3478° F., (v.) 2941° F.

9. Convert into the absolute scale :—(i.) 6° C., (ii.) 80° C., (iii.) −40° C., (iv.) −14° C., (v.) −100° C.

10. Convert into the absolute scale :—(i.) 70° F., (ii.) −4° F., (iii.) 104° F., (iv.) 2000° F., (v.) −37° F.

11. Convert (i.) 300°, (ii.) 400°, (iii.) 500°, on the absolute scale into the Centigrade, Réaumur, and Fahrenheit scales.

12. Convert each of the following temperatures into the other two scales : 42° F., −32° F., 327° R., −2° R., 78° C., and −172° C.

13. What temperature Fahrenheit corresponds to zero on the absolute scale ?

14. What temperature is expressed by the same number of degrees on the Centigrade and on the Fahrenheit scales ?

PRESSURES.

(*See Sect.* **2.**)

15. A pressure of 1000 lbs. per square inch is how many kilos. per square millimetre ?

16. When the mercury (Δ 13·596) barometer stands at 76 cm. how high will one of glycerin (Δ 1·27) stand ?

17. When the mercury (Δ 13·596) barometer stands at 760 mm. how high would one of hydrogen sulphate (Δ 1·842) stand?

18. When the barometer stands at 31 inches, what is it in millimetres?

19. When the barometer stands at 755 mm. what is it in inches?

20. When the pressure of the air is 750 mm. of mercury (Δ 13·56) what is it in (α) feet of water, (β) pounds per square inch?

CHAPTER IV.

THE VOLUME OF A MASS OF GAS.

(*See Sect.* **6.**)

1. 1000 ccm. of gas are heated from 0° C. to 39° C. Find the new volume.

2. 1000 ccm. of gas are heated from −39° C. to 52° C. Find the new volume.

3. 743 ccm. of gas are heated from 47° C. to 83° C. Find the new volume.

4. The pressure on 10 ccm. of gas is 7 metres. If the pressure be reduced to 847 mm. what is the new volume?

5. 486 ccm. of gas under the pressure of 760 mm. occupy what volume under the pressure of 3 feet of mercury?

6. The pressure on 10 cubic feet of air is 3·5 feet of mercury. How many litres will the air measure under a pressure of 760 mm.?

7. 1000 ccm. of air at 13° C. occupy what volume at 65° C.?

8. If 300 ccm. of gas are measured off at 28° C., what will the volume become at −14° C.?

9. 155 l. of air at 150° C. are cooled to 0° C. Find the new volume.

10. A litre of gas is heated from 14° C. to 42° C. Find the new volume.

11. A litre of air at 39° C. is cooled to −26° C. Find the new volume.

12. 134 l. of air are heated from −30° C. to 60° C. Find the new volume.

13. 50 ccm. of gas at 10° C. occupy what volume at 24° C.?

14. 100 ccm. of air at 12° C. are heated until they occupy 145 ccm. Find the new temperature.

15. 1000 ccm. of air at −31·2° R. are heated to 172·4° F. What is the new volume?

16. 320 ccm. of gas are measured off at 91° C. and 950 mm. What is the normal volume?

17. 150 ccm. of gas are measured off at 10° C. and 500 mm. What does the volume become at 16·4° C. and 520 mm.?

18. 852 ccm. of air at 11° C. and 760 mm. are heated to 27° C., the pressure being increased to 900 mm. Find the new volume.

19. 542 ccm. of air at 269° C. and 900 mm. are cooled to −51° C., the pressure being decreased to 666 mm. Find the new volume.

20. 672 ccm. of air at −49° C. and 1111 mm. measure what at 357° C. and 1890 mm.?

21. 700 ccm. of air at 77° C. and 1000 mm. measure what at 163° C. and 872 mm.?

22. 546 ccm. of gas at 17° C. and 760° mm. are cooled to 0° C., the pressure being decreased to 600 mm. Find the new volume.

23. 1234 ccm. of gas at −39° C. and 500 mm. are heated to 39° C., the pressure being increased to 617 mm. Find the new volume.

24. A quantity of oxygen, which measures 230 l. at 14° C. and 740 mm., will measure what at 0° C. and 760 mm.?

25. What will 1000 ccm. of normal gas become at 16·5° C. and 735 mm.?

26. 146 ccm. of air at 72° C. and 480 mm. occupy what volume at 39° C. and 600 mm.?

27. 487 ccm. of air are measured off at 17° C. and 750 mm. How many ccm. will the air occupy at 267° C. and 1948 mm.?

28. 4362 ccm. of gas at 73° C. and 2422 mm. are cooled to 47° C. and the pressure is decreased to 1024 mm. Find the new volume.

29. A flask which will not bear a pressure of 1500 mm. is filled with normal oxygen and heated. At what temperature will it explode?

30. A volume of gas at 10° C. is under the pressure of the atmosphere and 60 mm. of mercury. What pressure in addition to the atmosphere is required to keep the volume constant at 300° C.?

31. At what temperature has air the same density as hydrogen at 0° C.?

32. 1234 ccm. of normal gas are cooled to −52° C., the pressure being decreased to 617 mm. Find the new volume.

33. 682 ccm. of air at 43° C. and 1000 mm. are heated to 97° C., the pressure being decreased to 740 mm. Find the new volume.

34. 146 l. of gas at 17° C. and 974 mm. are heated to 51° C., the pressure being decreased to 760 mm. Find the new volume.

35. 1000 ccm. of gas at 20° C. and 730 mm. occupy what volume at 0° C. and 760 mm.?

36. 123 ccm. of gas at 247° C. and 800 mm. are cooled to −26° C., the pressure being decreased to 780 mm. Find the new volume.

37. 1000 ccm. of air are heated from 0° C. to 72° C. and the pressure is decreased from 600 mm. to 400 mm. What is the new volume?

38. 20 ccm. of hydrogen at 27° C. and 762 mm. occupy what volume at −23° C. and 1270 mm.?

39. A few drops of water at 15° C. are passed up into a barometer standing at 30 inches. How high does the mercury stand?

40. A litre of saturated air at 20° C. and 755 mm. is dried. What does the air measure at the same temperature and pressure?

41. 200 ccm. of oxygen are measured off over water at 14° C. and 756 mm. What does the dry normal gas measure?

42. If a cubic foot of aqueous vapour at 0° C. and 760 mm. weighs 351·5 grains, how many grains does a cubic foot of saturated air at 59° F. and under a pressure of 30 inches weigh?

CHAPTER V.

OXYGEN. O = 16.

N.B. *In the easier sums "two volumes"* (Sect. **10**) *are taken as* 22·4 *litres and the coefficient of expansion of a gas as* $\frac{1}{273}$. *In the more difficult sums below the line, two volumes are taken as* 22·32 *litres and the coefficient of expansion as* 0·00367.

1. How much mercury and how much oxygen is obtained on heating 10 grams of mercuric oxide?

$$HgO = Hg + O.$$

2. How much oxygen is obtained on heating 522 grams of manganese dioxide?

$$3\,MnO_2 = Mn_3O_4 + O_2.$$

3. 50 gm. of potassium chlorate are heated, how much oxygen is evolved?

$$KClO_3 = KCl + 3O.$$

4. How much (α) mercuric oxide, (β) potassium chlorate, (γ) manganese dioxide is required to make 100 gm. of oxygen?

$$HgO = Hg + O.$$
$$KClO_3 = KCl + O_2.$$
$$3MnO_2 = Mn_3O_4 + O_2.$$

5. What volume is occupied by 20 grams of oxygen (O_2)?

6. What volume of oxygen can be obtained from 20 gm. of manganese dioxide by heating it (α) alone?

$$3MnO_2 = Mn_3O_4 + O_2.$$

(β) with strong hydrogen sulphate?

$$MnO_2 + H_2SO_4 = MnSO_4 + H_2O + O.$$

7. What volume of oxygen can be made from 100 gm. of potassium chlorate?

$$KClO_3 = KCl + O_3.$$

8. What volume of oxygen can be made from 100 gm. of mercuric oxide?

$$HgO = Hg + O.$$

9. How many grams do 20 l. of oxygen (O_2) weigh?

10. What is the mass of 189 ccm. of oxygen (O_2)?

11. How much potassium chlorate is required to make 112 l. of oxygen?

$$KClO_3 = KCl + O_3.$$

12. How much manganese dioxide is required to make 10 l. of oxygen?

$$3MnO_2 = Mn_3O_4 + O_2.$$

13. How much potassium chlorate is required to make 70 l. of oxygen?

$$KClO_3 = KCl + 3O.$$

14. 174 gm. of manganese dioxide are heated. What volume of oxygen is given off?

$$3MnO_2 = Mn_3O_4 + O_2.$$

15. On heating some potassium chlorate 298 gm. of potassium chloride were left. What mass of chlorate was heated and what mass of oxygen was formed?

$$KClO_3 = KCl + O_3.$$

16. What volume of oxygen at 15° C. is obtained on passing carbon dioxide over a kilogram of calcium plumbate heated to redness and then through slaked lime?

$$Ca_2PbO_4 + 2CO_2 = 2CaCO_3 + PbO + O.$$

17. The air at 13° C. from a cylindrical gas-holder 2 metres high and 1 metre across is passed over a red-hot mixture of lead oxide and chalk. How much calcium plumbate is formed?

$$PbO + O + 2CaCO_3 = 2CO_2 + Ca_2PbO_4.$$

18. How much litharge is required to charge a wedge-shaped gas bag a metre high and wide and half a metre thick with oxygen at 15° C.?

$$PbO + O + 2CaCO_3 = 2CO_2 + Ca_2PbO_4.$$

$$Ca_2PbO_4 + 2CO_2 = 2CaCO_3 + PbO + O.$$

19. 60 gm. of mercuric oxide are heated. What volume of oxygen at 91° C. and 380 mm. is given off?

$$HgO = Hg + O.$$

20. 270 gm. of mercuric oxide are heated. What volume of

oxygen at 0° C. and 760 mm. is given off? And what will the gas measure at 17° C. and 700 mm.?

$$HgO = Hg + O.$$

21. What mass of oxygen would occupy 13 l. at 12° C.? And how much manganese dioxide must be heated to obtain it?

$$3MnO_2 = Mn_3O_4 + O_2.$$

22. 400 gm. of potassium chlorate are heated. What volume of oxygen at 27° C. is evolved?

$$KClO_3 = KCl + O_3.$$

23. What volume of oxygen at 21° C. and 380 mm. can be obtained on heating 1000 gm. of potassium chlorate?

$$KClO_3 = KCl + 3O.$$

24. How much potassium chlorate must be heated to give 23 l. of oxygen at 14° C. and 740 mm.?

$$KClO_3 = KCl + 3O.$$

25. How much magnesium can be burnt in a globe containing 10 l. of oxygen at 13° C. and 836 mm.?

$$Mg + O = MgO.$$

26. If 481 gm. barium dioxide are heated, what volume of oxygen at 17° C. and 800 mm. is evolved?

$$BaO_2 = BaO + O.$$

27. A gram of bleaching powder is boiled with water and cupric oxide. What volume of oxygen at 14° C. is evolved?

$$CaOCl_2 = CaCl_2 + O.$$

28. A quantity of barium dioxide is suspended in water and decomposed by carbon dioxide. If 19·7 gm. of barium carbonate are formed, what volume of oxygen at 14° C. will be set free on boiling the solution of hydrogen dioxide?

$$BaO_2 + CO_2 + H_2O = BaCO_3 + H_2O_2.$$
$$H_2O_2 = H_2O + O.$$

29. What volume of oxygen, supposing that it remained gaseous at −140° C. and 245·2 metres of mercury, could be made from 613 gm. of potassium chlorate?

$$KClO_3 = KCl + 3O.$$

30. What would be the volume of the liquefied gas if the density of it be 0·89?

31. In one of Dumas and Boussingault's experiments the cupric oxide lost 59·789 gm., and 67·282 gm. of water were formed. Calculate the atomic weight of oxygen.

$$CuO + H_2 = Cu + H_2O.$$

32. What volume of liquid oxygen (Δ·89) could be obtained from 100 l. of the gas measured at 20° C. ?

33. What is the mass of 556 ccm. of oxygen (O_2) measured *over water* at 20° C. and 750 mm. ?

34. 10 gm. of potassium dichromate are boiled with hydrogen sulphate. What volume of oxygen at 20° C. is given off ?

$$K_2Cr_2O_7 + 4H_2SO_4 = K_2SO_4 + Cr_2(SO_4)_3 + 4H_2O + 3O.$$

35. What volume of oxygen measured *over water* at 13° C. and 751 mm. is obtained on heating 100 gm. of (α) manganese dioxide, (β) potassium dichromate with hydrogen sulphate ?

$$MnO_2 + H_2SO_4 = MnSO_4 + H_2O + O.$$
$$K_2Cr_2O_7 + 4H_2SO_4 = K_2SO_4 + Cr_2(SO_4)_3 + 4H_2O + 3O.$$

CHAPTER VI.

HYDROGEN. H = 1.

1. What volume is occupied by a gram of liquid hydrogen (Δ 0·07) ? If the boiling point is −238·5° C., what is it Fahrenheit ?

2. 100 gm. of zinc are dissolved in dilute hydrogen sulphate. What volume of hydrogen is given off ?

$$Zn + H_2SO_4 = ZnSO_4 + H_2.$$

3. How many kilos. of (α) zinc and (β) hydrogen sulphate are required to make 750 litres of hydrogen ?

$$Zn + H_2SO_4 = ZnSO_4 + H_2.$$

4. How many litres of hydrogen are obtained on dissolving 16 gm. of magnesium in dilute acid ?

$$Mg + H_2SO_4 = MgSO_4 + H_2.$$

5. How many grams of water are formed on burning 5 l. of hydrogen ?

$$H_2 + O = H_2O.$$

6. A balloon holds 64 cub. metres of normal hydrogen (H_2). How many kilos. does the gas weigh?

7. What is the mass of 506 l. of hydrogen (H_2) measured at $-20°$ C. and 770 mm.?

8. 100 gm. steam are passed over red-hot iron. What volume of hydrogen at 10° C. and 742 mm. is formed?

$$4H_2O + 3Fe = Fe_3O_4 + 4H_2.$$

9. 50 ccm. of hydrogen at 17° C. and 800 mm. are required. How much sodium must be thrown into water?

$$Na + H_2O = HNaO + H.$$

10. 4 l. of hydrogen are passed over heated cupric oxide. What loss of mass does the oxide undergo?

$$H_2 + CuO = Cu + H_2O.$$

11. 100 gm. of levigated iron are dissolved in dilute hydrogen sulphate. What volume of hydrogen at 15° C. is evolved?

$$Fe + H_2SO_4 = FeSO_4 + H_2.$$

12. 400 ccm. of hydrogen are measured off at 72° C. and 800 mm. What is the normal volume?

13. 10 gm. of steam are passed over red-hot iron. What volume of hydrogen at 13° C. and 711 mm. is obtained?

$$4H_2O + 3Fe = Fe_3O_4 + 4H_2.$$

14. How many litres of hydrogen at 10° C. and 770 mm. are obtained on passing 2 gm. of steam over red-hot iron?

$$4H_2O + 3Fe = Fe_3O_4 + 4H_2.$$

15. A balloon of 150 cub. metres capacity is to be filled with hydrogen at 11° C. and 768 mm. How many kilograms of zinc and of hydrogen sulphate must be used?

$$Zn + H_2SO_4 = ZnSO_4 + H_2.$$

16. A kilo. of zinc is placed in a strong copper vessel holding 4 l. which is then half filled with dilute hydrogen chloride. How much zinc is dissolved before the pressure reaches 120 atmospheres and the action ceases?

$$Zn + 2HCl = ZnCl_2 + H_2.$$

17. Find the true mass in lbs. of a cubic foot of normal hydrogen and of a cubic foot of normal air.

18. A spherical balloon 50 ft. in radius will contain how many lb. of hydrogen and how many lb. of air?

19. The hydrogen used at Woolwich has a lifting power of 71 lbs. per 1000 cubic ft. If the gas were pure, what would the lifting power be?

20. A kilo. of potassium formate, when heated with potassium hydrate, would give what volume of hydrogen, supposing it were still gaseous at −140° C. and under a pressure of 494 metres of mercury?

$$CHKO_2 + HKO = K_2CO_3 + H_2.$$

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21. How much zinc is required to obtain 100 l. of hydrogen at 91° C. and 800 mm.?

$$Zn + H_2SO_4 = ZnSO_4 + H_2.$$

22. How much zinc must be dissolved in acid to make 5 cub. metres of hydrogen at 15° C. and 740 mm.?

$$Zn + H_2SO_4 = ZnSO_4 + H_2.$$

23. How many ccm. of (α) magnesium (Δ 1·74), (β) zinc (Δ 7·2), (γ) iron (Δ 7·8), must be dissolved in acid to give 50 l. of hydrogen at 15° C.?

$$[MgZnFe] + H_2SO_4 = [MgZnFe]SO_4 + H_2.$$

24. What is the mass of a litre of hydrogen measured over water at 50° C. and 790 mm.?

25. 100 gm. of potassium formate are heated with potassium hydrate. What volume of hydrogen at 15° C. and 790 mm. is given off?

$$CHKO_2 + HKO = K_2CO_3 + H_2.$$

CHAPTER VII.

WATER, $H_2O = 18$.

1. 840·16 gm. oxygen are required to form 945·439 gm. of water. Calculate the percentage composition of water.

2. 10 gm. of water are decomposed by electricity. What volumes of hydrogen and of oxygen are evolved?

$$H_2O = H_2 + O.$$

3. What volume is occupied by 100 gm. of steam (H_2O) measured at 300° C.?

4. What is the volume of 1000 gm. of (α) sea-water Δ 1·026, (β) ice Δ 0·92?

5. 1000 gm. of sea-water (Δ 1·029) contain 35·9 gm. of solid matter

in solution. How many kilos. of solid matter are there in solution in a cubic kilometre of sea-water?

6. How many cubic feet are occupied by a ton of sea-water (Δ 1·029)?

7. A block of ice (Δ 0·92) weighs 280 kilos. Find its volume.

8. If the density of ice be 0·92, what volume will 1000 ccm. of water at 4° C. occupy when frozen?

9. An iceberg (Δ 0·92) floats in sea-water (Δ 1·027) with 30,000 cub. m. above the sea. What is the total volume of the berg?

10. Sea-water (Δ 1·026) contains 3 per cent. of sodium chloride (NaCl). How much sodium is there in a cubic metre of sea-water?

11. 1000 gm. of sea-water (Δ 1·027) contain 37 gm. of salt (Δ 2·16). What contraction do 1000 ccm. of water undergo during the solution of the salt?

12. 100 gm. of gypsum are heated. What volume of steam at 300° C. is given off?

$$CaSO_4 2H_2O = CaSO_4 + 2H_2O.$$

13. 100 gm. of each variety of sodium carbonate (i.) $Na_2CO_3 10H_2O$, (ii.) $Na_2CO_3 8H_2O$, (iii.) $Na_2CO_3 5H_2O$, (iv.) $Na_2CO_3 H_2O$ contain how many grams of water?

14. A tube containing cupric oxide, which weighed 105·6 gm., after being heated to redness in a current of hydrogen weighed 101·6 gm. The drying apparatus weighed 80·3 gm. before and 84·8 gm. after the experiment. How much oxygen unites with one part of hydrogen?

$$h + o = ho.$$

15. If 88·88 parts of oxygen unite with 11·11 parts of hydrogen, and the equivalent of oxygen be 100, what is the equivalent of hydrogen?

$$h + o = ho.$$

16. In one of Dumas's experiments to ascertain the composition of water by passing hydrogen over heated cupric oxide the following results were obtained:—

Mass of cupric oxide and tube before the experiment,	334·598 gm.
,, ,, ,, after ,,	314·236 ,,
Mass of drying tubes before the experiment	426·358 ,,
,, ,, after ,,	449·263 ,,

Calculate the percentage composition of water by mass.

17. 100 gm. of steam are passed over red-hot iron. What volume of hydrogen at 14° C. and 730 mm. is formed?

$$4H_2O + 3Fe = Fe_3O_4 + 4H_2.$$

18. 10 ccm. of sodium (Δ 0·97) are thrown into water. What volume of hydrogen at 18° C. and 570 mm. is evolved ?

$$Na + H_2O = HNaO + H.$$

19. What volume of oxygen at 12° C. and 762 mm. is evolved on decomposing 1 gm. of water by electricity ?

$$H_2O = H_2 + O.$$

20. 500 ccm. of hydrogen at 39° C. are exploded with 500 ccm. of oxygen under a pressure of 332·5 mm. What volume of which gas is left ?

$$H_2 + O = H_2O.$$

21. How much water must be electrolysed to give a litre of gas at 15° C. and 740 mm. ?

$$H_2O = H_2 + O.$$

22. 400 troy ounces of water at 16° R. are mixed with 400 avoirdupois ounces at 95° F. Find the mass of the mixture in grams and the temperature of it Centigrade.

23. How many grams of steam must be passed into 100 gm. of water at 0° C. in which 10 gm. of ice are floating to raise the temperature of the whole to 50° C. ?

24. 1 ccm. of water at 4° C. forms how many times its volume of steam at 300° C. ?

25. Find the density of steam at 300° C. referred to air at 0° C.

26. A pound of dry steam at 374° F. occupies how many cubic feet ?

27. 2 grams of silver oxide are thrown into hydrogen dioxide. What volume of oxygen at 13° C. is given off ?

$$Ag_2O + H_2O_2 = Ag_2 + H_2O + O_2.$$

28. Pure hydrogen dioxide (Δ 1·455) gives how many times its volume of oxygen when boiled ?

$$H_2O_2 = H_2O + O.$$

29. A solution of hydrogen dioxide (Δ 1·455) gives twenty times its volume of oxygen when boiled. Find its percentage composition by mass.

$$H_2O_2 = H_2O + O.$$

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30. How many grains does a cubic foot of aqueous vapour, measured at 212° F. and 30 inches of mercury, weigh ?

31. What volume of oxygen at 10° C. can be obtained on boiling 10 grams of hydrogen dioxide ?

$$H_2O_2 = H_2O + O.$$

32. 100 gm. of solution of hydrogen dioxide in water when boiled gave 5 litres of oxygen at 12° C. and 750 mm. Find the percentage of hydrogen dioxide in the solution.

$$H_2O_2 = H_2O + O.$$

33. According to Chaney a cubic foot of water at 62° F. weighs 62·278601 lb. against brass (Δ 8·143) weights in air. If a volume of water at 39° F. becomes 1·00112 volumes at 62° F., how many pounds does a cubic foot of water at 39° F. weigh in vacuo?

CHAPTER VIII.

NITROGEN, N = 14.

1. What do 100 l. of nitrogen (N_2) weigh?

2. 146 ccm. of nitrogen at 17° C. and 974 mm. are heated to 51°, the pressure being decreased to 760 mm. Find the new volume.

3. What volume of nitrogen can be obtained from 10 gm. of ammonium nitrite?

$$NH_4NO_2 = 2H_2O + N_2.$$

4. 128 gm. of ammonium nitrite are heated. What volume of nitrogen at 39° C. and 950 mm. is given off?

$$NH_4NO_2 = 2H_2O + N_2.$$

5. 100 gm. of lead nitrate when heated were found by Svanberg to leave 67·4016 gm. of lead oxide. If O = 100 and Pb = 1294, what is the atomic weight of nitrogen?

$$Pb2NO_3 = PbO + O + 2NO_2.$$

6. 30 ccm. of nitrogen were measured off at 18° C. in a tube. The barometer stood at 750 mm. and the mercury in the tube at 120 mm. Find the normal volume of the gas and its mass in grams.

7. What is the mass of 270 ccm. of nitrogen measured over water at 8° C. and 768 mm.?

8. 3 gm. of urea are warmed with potassium nitrite and hydrogen sulphate. What volume of nitrogen and of carbon dioxide is given off?

$$CON_2H_4 + N_2O_3 = 2N_2 + 2H_2O + CO_2.$$

HYDROGEN NITRATE, HNO_3 = 63.

9. How many pounds of hydrogen nitrate are obtained on distilling 400 lbs. of sodium nitrate with hydrogen sulphate?

$$2NaNO_3 + H_2SO_4 = Na_2SO_4 + 2HNO_3.$$

10. What volume is occupied by 10,000 gm. of hydrogen nitrate (Δ 1·5)?

11. How much oxygen is there in a litre of hydrogen nitrate (HNO_3), the density of which is 1·5 ?

12. What volume of hydrogen sulphate (Δ 1·84) must be distilled with 1 kilo. of sodium nitrate, and what volume of hydrogen nitrate (Δ 1·5) will be formed ?

$$NaNO_3 + H_2SO_4 = HNaSO_4 + HNO_3.$$

13. How many grams of hydrogen nitrate can be obtained from a kilo. of sodium nitrate ?

$$NaNO_3 + H_2SO_4 = HNaSO_4 + HNO_3.$$

14. What is the least quantity of hydrogen sulphate which can be used to decompose 500 gm. of potassium nitrate ?

$$2KNO_3 + H_2SO_4 = K_2SO_4 + 2HNO_3.$$

15. How much potassium nitrate and what volume of hydrogen sulphate (Δ 1·842) must be distilled together to form a litre of hydrogen nitrate (Δ 1·52) ?

$$KNO_3 + H_2SO_4 = HKSO_4 + HNO_3.$$

16. Hydrogen nitrate (Δ 1·353) at 15° C. contains 56 per cent. of real acid. Find a formula for it.

17. When hydrogen nitrate is distilled under ordinary pressures, at about 120° C., an acid (Δ 1·44) containing 70 per cent. of real acid passes over. Find a formula for it.

18. Ordinary hydrogen nitrate (Δ 1·4) contains 65·07 per cent. by mass of real acid. What volume of such an acid must be made up to one litre, that 1 ccm. may contain 0·63 gm. of real acid ?

19. How much hydrogen nitrate is required to neutralize a solution of 800 gm. of potassium hydrate ?

$$HKO + HNO_3 = H_2O + KNO_3.$$

20. How much quick-lime is left on heating 1000 gm. of calcium nitrate ?

$$Ca2NO_3 = CaO + O + 2NO_2.$$

21. How many kilos. of tin must be heated with hydrogen nitrate to form 10 lbs. of stannic oxide.

$$Sn + 4HNO_3 = 4NO_2 + 2H_2O + SnO_2.$$

22. How many ounces of silver nitrate are formed by the action of hydrogen nitrate (Δ 1·4) upon 1,000 gm. of silver ?

$$6HNO_3 + 4Ag = 4AgNO_3 + 3H_2O + N_2O_3.$$

23. How much ammonium nitrate is formed by dissolving 4 gm. of zinc in hydrogen nitrate (Δ 1·4) ?

$$10HNO_3 + 4Zn = 4Zn2NO_3 + 3H_2O + H_4NNO_3.$$

24. What volume of nitrogen at 17° C. is evolved on heating 100 gm. of copper with hydrogen nitrate (Δ 1·4)?

$$12HNO_3 + 5Cu = 5Cu2NO_3 + 6H_2O + N_2.$$

25. A cylindrical iron bottle a foot high and six inches across inside is to be filled with nitrous oxide at 15° C. and under 40 atmospheres pressure. How many grams of zinc must be dissolved in hydrogen nitrate (Δ 1·1)?

$$10HNO_3 + 4Zn = 4Zn2NO_3 + 5H_2O + N_2O.$$

26. What volume of hydrogen nitrate (Δ 1·52) and mass of phosphorus pentoxide must be distilled together to form 100 gm. of nitrogen pentoxide?

$$2HNO_3 + P_2O_5 = 2HPO_3 + N_2O_5.$$

THE OXIDES OF NITROGEN.

27. Calculate the percentage composition of ammonium nitrate, NH_4NO_3.

28. What volume of nitrous oxide can be obtained from 240 grams of ammonium nitrate?

$$NH_4NO_3 = 2H_2O + N_2O.$$

29. How much ammonium nitrate is required to make 40 l. of nitrous oxide?

$$NH_4NO_3 = 2H_2O + N_2O.$$

30. What is the mass of 100 l. of (α) nitrous oxide N_2O, (β) nitric oxide NO?

31. What volume of nitrous oxide at 15° C. and 740 mm. is given by 30 gm. of ammonium nitrate?

$$NH_4NO_3 = 2H_2O + NO_2.$$

32. What volume of hydrogen is required to combine with the oxygen contained in 10 gm. of nitrous oxide?

$$N_2O + H_2 = H_2O + N_2.$$

33. How much phosphorus can be burnt in 4 l. of nitrous oxide measured at 14° C.?

$$P_2 + 5N_2O = P_2O_5 + 5N_2.$$

34. What volume is occupied by 13 gm. of nitric oxide NO?

35. How much copper is required to form 10 l. of nitric oxide?

$$3Cu + 8HNO_3 = 3Cu2NO_3 + 4H_2O + 2NO.$$

36. What volume of nitric oxide at 13° C. is obtained on dissolving 25 gm. of copper in hydrogen nitrate?

$$3Cu + 8HNO_3 = 3Cu2NO_3 + 4H_2O + 2NO.$$

37. 127 gm. of copper are dissolved in hydrogen nitrate. What volume of nitric oxide at 14° C. and 1000 mm. is evolved?

$$3Cu + 8HNO_3 = 3Cu2NO_3 + 4H_2O + 2NO.$$

38. What volume of nitric oxide is obtained on boiling 50 gm. of hydrogen nitrate with acidified ferrous sulphate?

$$2HNO_3 + 3H_2SO_4 + 6FeSO_4 = 3Fe_23SO_4 + 4H_2O + 2NO.$$

39. 5 ccm. of mercury (Δ 13·55) are warmed with hydrogen nitrate. What volume of nitric oxide at 21° C. is evolved?

$$3Hg + 8HNO_3 = 3Hg2NO_3 + 4H_2O + 2NO.$$

40. 100 gm. of cuprous oxide are warmed with dilute hydrogen nitrate. What volume of nitric oxide is evolved?

$$3Cu_2O + 14HNO_3 = 6Cu2NO_3 + 7H_2O + 2NO.$$

41. 4 l. of nitric oxide at 17° C. and 750 mm. are passed over red-hot copper. What volume of nitrogen at 7° C. and 600 mm. is evolved?

$$2NO + 2Cu = 2CuO + N_2.$$

42. What volume of oxygen is required to convert 10 gm. of nitric oxide in presence of water into hydrogen nitrate?

$$2NO + H_2O + 3O = 2HNO_3.$$

43. 300 gm. of dry lead nitrate are heated. What volume of nitrogen tetroxide at 100° C. is evolved?

$$Pb2NO_3 = PbO + O + 2NO_2.$$

44. Excess of carbon is thrown into 100 gm. of fused potassium nitrate. What volume of nitrogen and of carbon dioxide is evolved?

$$4KNO_3 + 5C = 2K_2CO_3 + 2N_2 + 3CO_2.$$

45. At 27° C. nitrogen tetroxide is 2·65 times as heavy as air, and at 180° C. it is 1·57 times as heavy. Find the corresponding molecular weights.

46. Find the percentage composition of (α) nitroxyl chloride NOCl and (β) nitryl chloride NO_2Cl.

47. What volume of chlorine at 15° C. must be passed over 20 gm. of silver nitrate to obtain nitrogen pentoxide?

$$Cl_2 + 2AgNO_3 = 2AgCl + O + N_2O_5.$$

48. 25·82 ccm. of nitric oxide diffuse through a certain apparatus in 50 seconds. What volume of hydrogen will diffuse under the same conditions?

AMMONIA, $NH_3 = 17$.

49. How many grams of ammonia can be obtained from 2140 gm. of ammonium chloride?

$$2NH_4Cl + CaO = CaCl_2 + H_2O + 2NH_3.$$

50. What volume of ammonia is obtained from 31·47 gm. of ammonium chloride?

$$2NH_4Cl + CaO = CaCl_2 + H_2O + 2NH_3.$$

51. What volume is occupied by 100 gm. of ammonia?

52. How much ammonium chloride must be heated with lime to make 80 l. of ammonia?

$$2NH_4Cl + CaO = CaCl_2 + H_2O + 2NH_3.$$

53. What volume is occupied by 20 gm. of ammonia at 12° C. and 730 mm.?

54. What volume of ammonia at 15° C. and 740 mm. could be obtained from 214 gm. of ammonium chloride?

$$2NH_4Cl + CaO = CaCl_2 + H_2O + 2NH_3.$$

55. How many grams of ammonia are obtained on passing 3 gm. of nitric oxide mixed with excess of hydrogen over hot spongy platinum?

$$2NO + 10H = 2NH_3 + 2H_2O.$$

56. How much do 2 l. of solution of ammonia (Δ ·88) weigh?

57. What volume of ammonia is required to neutralize 10 gm. of hydrogen chloride?

$$HCl + NH_3 = NH_4Cl.$$

58. 29 ccm. of ammonia are decomposed by a series of electric sparks and the mixed gases are exploded with 30 ccm. of oxygen. What volumes of what gases remain?

$$2NH_3 = 3H_2 + N_2.$$
$$3H_2 + 3O = 3H_2O.$$

59. What volume of ammonia will diffuse under the same conditions as 84 ccm. of sulphur dioxide (SO_2)?

60. 2 gm. of potassium are heated in ammonia. How much potassamide and what volume of hydrogen at 15° C. is formed?

$$K + NH_3 = KH_2N + H.$$

61. 10 gm. of solution of ammonia when mixed with sodium hypobromite gave 1 l. of nitrogen at 7° C. Find the percentage of ammonia in the solution.

$$3NaBrO + 2NH_3 = 3NaBr + 3H_2O + N_2.$$

62. A substance contains silver 78·25 per cent., nitrogen 10·15 per cent., and oxygen 11·59 per cent. Find its formula.

63. Find the percentage composition of dimercurammonium iodide (NHg_2I).

64. Excess of phosphorus is burnt in 10 l. of nitrous oxide at 5° C. What volume of nitrogen at 15° C. is left?

$$P_2 + 5N_2O = P_2O_5 + 5N_2.$$

65. 2 l. of nitryl chloride at 15° C. are passed over warm silver nitrate. How much nitrogen pentoxide is formed?

$$NO_2Cl + AgNO_3 = AgCl + N_2O_5.$$

66. 1 ccm. of liquid ammonia (Δ ·63) under the pressure of 5 atmospheres is heated from 0° C. to 20° C. What volume will the gas occupy?

67. Find the percentage composition of (α) hydrazine (N_2H_4) and (β) azoimide (N_3H).

68. A body contains 64·62 per cent. of nitrogen and 35·38 per cent. of sodium. Find a formula for it.

CHAPTER IX.

THE ATMOSPHERE.

A litre of normal air weighs 1·293 *grams; or a cubic foot weighs* 0·0807 *lb. Air contains* 21 *per cent. by volume and* 23·3 *per cent. by mass of oxygen.*

1. In one of Dumas' experiments to determine the composition of air by passing it over heated copper:—

Mass of tube and copper before the experiment	120	gm.
,, ,, after ,,	121·15	,,
Mass of the globe exhausted	852	,,
,, ,, and nitrogen	855·85	,,

Calculate the percentage composition of air by mass and by volume.

2. 100 l. of air are passed over red-hot copper. How much does the copper increase in mass?

$$Cu + O = CuO.$$

3. 20 ccm. of air are mixed with 30 ccm. of hydrogen and exploded. What volumes of what gases are left?

$$H_2 + O = H_2O.$$

4. 16·7 ccm. of air when mixed with hydrogen in a Ure's eudiometer measured 29 ccm. After the explosion the residual gas measured 18·5 ccm. What is the percentage by volume of oxygen in the air?

$$H_2 + O = H_2O.$$

5. How much phosphorus is required to remove the oxygen from a litre of air?

$$P_2 + O_5 = P_2O_5.$$

6. How much phosphorus must be burnt in what volume of air at 0° C. to make 15·8 l. of nitrogen at 13° C.?

$$P_2 + O_5 = P_2O_5.$$

7. How much phosphorus is required to remove the oxygen from 100 l. of air at 15° C. and 740 mm.?

$$P_2 + O_5 = P_2O_5.$$

8. According to Vernon Harcourt a mixture of air and ammonia passed over red-hot copper gives pure nitrogen. How much nitrogen can be obtained from 100 l. of air, and how many ccm. of solution of ammonia containing 700 times their volume of the gas are used?

$$2NH_3 + 3O = 3H_2O + N_2.$$

9. At what temperature does a litre of air weigh a gram?

10. What volume of air (cont. ·04 per cent. by vol. of carbon dioxide) must be drawn through lime-water to precipitate 1 gram of calcium carbonate?

$$CaH_2O_2 + CO_2 = H_2O + CaCO_3.$$

11. What is the difference in mass between 10 l. of air at 15° C. and 10 l. of nitrogen under 775·62 mm.?

12. On October 14th, 1881, the pressure of the wind at Greenwich was 53 lbs. per sq. ft. How many grams per scm. was it?

13. A man inhales 18 cub. ft. of air per hour. How many pounds of oxygen does he require in 24 hours?

14. Westminster Hall is 290 ft. long, 68 ft. wide, and 110 ft. high. How many tons of air does it contain?

15. What is the mass of 500 cub. metres of air at 21° C.?

16. Find the mass of 640 ccm. of air measured at 546° C. and 712 mm.

17. How many pounds of air at 15° C. are there in a room 30 ft. long, 22 ft. wide, and 15 ft. high? And what mass of oxygen is there in the air?

18. How many kilograms of air are there in a room 17 ft. 6 in. long, 14 ft. wide, and 10 ft. high?

19. It is calculated that the mass of the atmosphere is equal to that of 581,000 cubic kilometres of copper (Δ 8·9). Find the radius of an iron (Δ 7·8) sphere equal in mass to the atmosphere.

20. An inch of rainfall is how many tons of water per acre?

21. The area of the basin of the Thames is 6000 square miles. A rainfall of 3·937 inches upon it is how many cubic metres of water?

22. 176·1 ccm. of air were measured off at 10° C. after saturation with aqueous vapour. The barometer stood at 747·2 mm. and the mercury in the tube at 70 mm. Find the normal volume of the air.

23. After absorption by pyrogallate the nitrogen measured 142·8 ccm. at 8° C. The barometer stood at 754·8 mm. and the mercury in the tube at 96·8 mm. Find the percentage by volume of oxygen in the air of the last question.

24. How much moist iron can be oxidized by 1000 l. of air at 13° C.?

$$2Fe + 3O = Fe_2O_3.$$

25. How much sulphur can be burnt in 20 l. of air at 26° C.?

$$S + O_2 = SO_2.$$

26. What volume of air at 21° C. must be passed over 100 gm. of copper to convert it into cupric oxide?

$$Cu + O = CuO.$$

27. How much magnesium can be burnt in a globe containing 5 l. of air at 21° C. and 740 mm.?

$$Mg + O = MgO.$$

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28. 146 ccm. of air at 10° C. and 730 mm. are measured off over water. What would the dry normal air measure?

29. A cubic mile of air at 760 mm. and 30° C. is saturated with aqueous vapour. How many tons of rain will fall if the temperature sink to 0° C.?

30. A mass of air a mile square and 100 ft. thick is saturated with aqueous vapour at 10° C. If the temperature fall to 5° C. how many tons of rain will fall?

31. 500 gm. of carbon are burnt in 60 cub. metres of air at 14° C. free from carbon dioxide. Find the percentage of oxygen, nitrogen, and carbon dioxide in the air after the experiment.

$$C + O_2 = CO_2.$$

32. A vessel of water at 99° C. weighing, when reduced to water, 50 kilo. was placed in a room, the walls of which are 10 m. each way and impervious to heat, containing normal air (sp. ht. 0·168). Find the temperature of the air and the increase in pressure on each scm. of the walls.

33. 1000 cub. metres of gas at 18° C. and 765 mm. are put into a balloon of 1250 cub. metres capacity. After ascending a certain height the temperature is found to be 8° C. and the balloon is fully distended. Find the height of the barometer in the balloon and the distance of the balloon from the earth.

34. If the earth be a sphere of 6,371,300 metres radius and the pressure of the air (containing ·04 per cent. of carbon dioxide CO_2 by mass) be 1·0333 kilo. per scm., find the mass of the carbon in the atmosphere.

35. In one of Lord Rayleigh's experiments 7925 ccm. of air left 65 ccm. of argon. What is the percentage by volume of argon in the atmosphere?

36. If the density of argon be 19·9, what do 100 ccm. of it weigh?

CHAPTER X.

Carbon C = 12.

1. The Kohinoor (Δ 3·5) weighs 329·6 grains, and the Rajah of Borneo 1174·4 grains. Find the volume of each diamond in ccm.

2. How many pencil-leads 2 mm. square and a decimetre long can be cut from a kilo. of graphite (Δ 2·25)?

3. The specific heat of graphite is 0·198. What is its probable atomic weight?

4. The density of anthracite is about 1·6. How many lbs. does a cubic foot weigh?

5. The density of ordinary coal is about 1·3. Find the mass of a cubic yard in tons.

6. In 1881, 4427 million cubic feet of coal were raised in Great Britain. If it were piled into a cube, find the length of each edge in metres.

Carbon Monoxide CO = 28.

7. How many litres of carbon dioxide must be passed over red-hot charcoal to produce 84 gm. of carbon monoxide?

$$CO_2 + C = 2CO.$$

8. 10 l. of carbon monoxide at 14° C. and 760 mm. are required. What volume of normal carbon dioxide must be passed over red-hot carbon and what mass of carbon is absorbed?

$$CO_2 + C = 2CO.$$

9. 38 l. of carbon monoxide at 18° C. and 672 mm. are required. How much dry hydrogen oxalate must be used?

$$C_2H_2O_4 = H_2O + CO_2 + CO.$$

10. 100 l. of carbon monoxide at 68° F. are required. How much crystallized hydrogen oxalate must be used?

$$C_2H_2O_4 2H_2O = 3H_2O + CO_2 + CO.$$

11. 4 gm. of potassium ferrocyanide are heated with hydrogen sulphate. What volume of carbon monoxide at 13° C. and 770 mm. is evolved?

$$K_3Fe_2C_{12}N_{12}6H_2O + 6H_2O + 12H_2SO_4 = 4K_2SO_4 + 2FeSO_4 + 6(NH_4)_2SO_4 + 12CO.$$

12. What volume is occupied by 100 gm. of (α) carbon monoxide CO (β) carbon dioxide CO_2?

13. Find the mass of 10 l. of carbon monoxide measured at 39° C. and 800 mm.

14. 30 ccm. of carbon monoxide are exploded with excess of oxygen and 35 ccm. of gas remain. What volume of oxygen was added?

$$2CO + O_2 = 2CO_2.$$

15. 50 ccm. of a mixture of carbon monoxide and hydrogen are exploded with excess of oxygen. 30 ccm. of gas remain, of which 20 ccm. are absorbed by potassium hydrate. What was the volume of the carbon monoxide and of the oxygen?

$$2CO + O_2 = 2CO_2.$$
$$2H_2 + O_2 = 2H_2O.$$

16. Find the formula of a substance containing carbon 20 per cent., oxygen 26·6 per cent., and sulphur 53·3 per cent.

CARBON DIOXIDE $CO_2 = 44$.

17. A diamond weighing 7 gm. is burnt in oxygen. What volume of carbon dioxide is formed?

$$C + O_2 = CO_2.$$

18. 10 gm. of alcohol are burnt. What volume of carbon dioxide is formed?

$$C_2H_6O + 6O = 3H_2O + 2CO_2.$$

19. 10 gm. of hexane are burnt. What volume of carbon dioxide is formed?

$$C_6H_{14} + 19O = 7H_2O + 6CO_2.$$

20. 10 lbs. of paraffin candles are burnt. What mass of carbon dioxide and of water is formed?

$$C_{20}H_{42} + 61O = 20CO_2 + 21H_2O.$$

21. What volume of carbon dioxide at 12° C. and 750 mm. is produced on dissolving 10 gm. of marble in hydrogen chloride?

$$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2.$$

22. How much chalk must be dissolved in acid to give 5 l. of carbon dioxide at 12° C. and 750 mm.

$$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2.$$

23. 8·96 l. of carbon dioxide at 31° C. and 912 mm. are required. How much marble must be used?

$$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2.$$

24. How much marble must be dissolved in acid to give 20 l. of carbon dioxide at 18° C. and 740 mm.?

25. How many ounces of sodium and hydrogen carbonate and of hydrogen tartrate must be used to charge a gasogen holding 4 l. with gas under a pressure of 4 atmo. at 10° C.? (1 vol. water at 10° C. absorbs 1·1847 vol. of normal carbon dioxide.)

$$HNaCO_3 + C_4H_6O_6 = C_4H_5NaO_6 + H_2O + CO_2.$$

26. What volume of air is required to burn a kilo. of carbon?

$$C + O_2 = CO_2.$$

27. How much carbon is there in a litre of carbon dioxide?

28. 200 gm. of platinum (sp. ht. 0·032) are cooled in solid carbon dioxide and dropped into 100 gm. of water at 16° C. If the temperature of the water fall to 10° C. what is the temperature of the carbon dioxide?

29. Calcium hydrate is soluble in 730 times its mass of water. What volume of carbon dioxide at 13° C. is required to precipitate the calcium from 3000 gm. of lime water?

$$CaH_2O_2 + CO_2 = H_2O + CaCO_3.$$

30. What is the percentage composition of potassium cyanide (KCN)?

MARSH GAS $CH_4 = 16$. ETHENE $C_2H_4 = 28$.
ACETYLENE $C_2H_2 = 26$.

31. Find the mass of 76 l. of marsh-gas measured at 31° C.

32. Find the mass of a litre of (α) ethine C_2H_2 (β) ethene C_2H_4.

33. 15·2 l. of methane at 17° C. and 870 mm. are required. How much dry sodium acetate must be used?

$$2NaC_2H_3O_2 + BaH_2O_2 = BaCO_3 + Na_2CO_3 + 2CH_4.$$

34. What is the mass of 3·73 l. of ethene measured at 100° C.?

35. What volume of ethene at 16° C. and 750 mm. is required to saturate 100 ccm. of bromine (Δ 3)?

$$C_2H_4 + Br_2 = C_2H_4Br_2.$$

36. 25 ccm. of ethene are exploded with 100 ccm. of oxygen. What volume of carbon dioxide is formed, and of oxygen is left?

$$C_2H_4 + 3O_2 = 2H_2O + 2CO_2.$$

37. 374·166 ccm. of hydrogen diffuse through a certain apparatus in 10 seconds. What volume of ethene will diffuse under the same conditions?

38. What volume of cyanogen at 15° C. is given off on heating 3 gm. of mercuric cyanide?

$$HgC_2N_2 = Hg + C_2N_2.$$

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39. 100 gm. of crystallized hydrogen oxalate are heated with hydrogen sulphate. What volume of carbon monoxide at 30° C. and 747 mm. is evolved?

$$C_2H_2O_42H_2O = 3H_2O + CO_2 + CO.$$

40. 100 l. of carbon monoxide at 14° C. and 1000 mm. are required. How much sodium formate must be heated with hydrogen sulphate?

$$NaCHO_2 + H_2SO_4 = NaHSO_4 + H_2O + CO.$$

41. 15·3 gm. of copper are dissolved in hydrogen nitrate. What volume of nitric oxide at 15° C. and 765 mm. is evolved, and how many ccm. of carbon disulphide (Δ 1·25) can be burnt in it?

$$3Cu + 8HNO_3 = 3Cu2NO_3 + 4H_2O + 2NO.$$
$$CS_2 + 6NO = 6N + CO_2 + 2SO_2.$$

42. A bubble of marsh gas (CH_4) ascends from the bottom of a pool 3 m. deep, and is found to measure 20 ccm. over water which stood at 170 mm. in the tube. If the temperature was 14° C. and the barometer stood at 750 mm. find the radius of the bubble when at the bottom of the pool and the mass of the marsh-gas.

VAPOUR DENSITIES.

43. Find the mass of 295 ccm. of camphor ($C_{10}H_{16}O$) vapour at 210° C.

44. A globe the volume of which was 810 ccm. when full of air at 14° C. weighed 119 gm. and when full of alcohol vapour at 100° C. weighed 119·2 gm. Find the density of the vapour.

45. A globe the capacity of which was 178 ccm. when filled with air at 15° C. weighed 23·45 gm. and when filled with the vapour of a hydrocarbon at 110° C. weighed 23·72 gm. Find the density of the vapour.

46. 0·1 gm. of carbon disulphide gave 90 ccm. of vapour at 100° C. by Hofmann's method. The barometer (reduced) stood at 767 mm. and the mercury in the tube at 170 mm. Find the density of the vapour.

47. 0·12 gm. of dibromamylene gave in Meyer's third method 13·1 ccm. of air at 17° C. and 758 mm. Find the density of the vapour.

48. 0·1105 gm. of phenyl-naphthalene gave 13·2 ccm. of nitrogen at 17·5° C. and 754·1 mm. in Meyer's third method. Find the density of the vapour.

PERCENTAGE COMPOSITION AND FORMULA.

Find the formula of a substance containing :—

49. Carbon 45, hydrogen 7·5, and oxygen 60 parts.

50. Carbon 26·66, oxygen 53·33, and water 20 %.

51. Carbon 39·56, hydrogen 7·69, and oxygen 52·75 %.

52. Carbon 74·07, hydrogen 8·64, and nitrogen 17·29 %.

53. Carbon 19·04, hydrogen 4·76, sulphur 25·4, and oxygen 50·8 %.

54. Carbon 53·16, hydrogen 6·3, and oxygen 40·54 %.

55. Carbon 50·37, hydrogen 6·33, nitrogen 17·95, and oxygen 25·36 %.

56. Carbon 49·485, hydrogen 5·155, nitrogen 28·866, oxygen 16·495 %.

57. Carbon 35·71, hydrogen 2·38, nitrogen 33·33, and oxygen 28·58 %.

58. A substance contains carbon 68·67 %, hydrogen 4·95 %, and oxygen 26·38 %. If the vapour is 4·226 times heavier than air, find the formula of the substance.

59. 0·25 gm. of an organic substance gave 0·8103 gm. of carbon dioxide and 0·2655 gm. water. If the vapour is 3·76 times heavier than air, find the formula of it.

60. 0·243 gm. of a substance containing only carbon, hydrogen and oxygen gave 0·693 gm. of carbon dioxide, and 0·162 gm. of water. Find the simplest formula for it.

61. 0·3807 gm. of an organic acid gave 0·9575 gm. of carbon dioxide and 0·1698 gm. of water. 0·4287 gm. of the silver salt left 0·202 gm. of silver. Find the formula of the acid.

62. Mauveine is found to contain carbon 73·55, hydrogen 5·67, and nitrogen 12·73 %. 0·55 gm. of the platinochloride contains ·088 gm. of platinum. Find the formula of the base.

63. 4·85 gm. of an organic substance gave 6·95 gm. of carbon dioxide and 0·95 gm. of water. 5·46 gm. of it gave 681 ccm. of nitrogen at 13° C. and 775 mm. Calculate its percentage composition and formula.

64. 0·4102 gm. of a liquid gave when burnt with lead chromate 0·5119 gm. of carbon dioxide and 0·2286 gm. of water. 0·3878 gm. of it gave 0·3975 gm. of silver iodide and 0·0148 gm. of silver. Calculate its percentage composition and formula.

Find the molecular weight of the dissolved substance in each of the following cases:—

65. 0·164 gm. of alcohol (C_2H_6O) dissolved in 100 gm. of benzene lowered the freezing-point 0·175° C.

66. 12·73 gm. of naphthalene ($C_{10}H_8$) dissolved in 100 gm. of benzene lowered the freezing-point 4·9° C.

67. 12·616 gm. of dextrose ($C_6H_{12}O_6$) dissolved in 92·25 gm. of water lowered the freezing-point 1·45° C.

68. 7·49 gm. of gum arabic dissolved in 100 gm. of water lowered the freezing-point 0·03° C.

69. 7·034 gm. of camphor ($C_{10}H_{16}O$) dissolved in 100 gm. of ether ($C_4H_{10}O$) lowered the pressure by 29 mm. from 853·8 mm.

70. A bulb containing a solution of 4·1 gm. of nitro-benzene in 46 gm. of alcohol (C_2H_6O) lost 2·034 gm. during the passage of a current of dry air, while a bulb containing alcohol lost 0·0684 gm.

71. 1·065 gm. of iodine dissolved in 30·14 gm. of ether raised the boiling-point 0·296° C.

72. 1·4475 gm. of phosphorus dissolved in 54·65 gm. of carbon disulphide (CS_2) raised the boiling-point 0·486° C.

73. 0·552 gm. of naphthalene ($C_{10}H_8$) dissolved in 9·5 ccm. of chloroform raised the boiling-point 1·2° C.

74. 0·558 gm. of hydrogen benzoate ($C_7H_6O_2$) raised the boiling-point of 20·8 ccm. of ether 0·66° C.

75. 1·169 gm. of urea (CON_2H_4) raised the boiling-point of water 1·24° C.; the volume of the solution was 8·1 ccm.

76. 1·33 gm. of potassium bromide (KBr) raised the boiling-point of water 0·38° C., the volume of the solution was 13·5 ccm.

CHAPTER XI.

CHLORINE, Cl = 35·5.

1. What volume is occupied by 177·5 gm. of chlorine (Cl_2)?

2. How much manganese dioxide is required to make 100 gm. of chlorine from hydrogen chloride?

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2.$$

3. What volume of chlorine can be made from 2078 gm. of salt?

$$2NaCl + MnO_2 + 2H_2SO_4 = 2H_2O + Na_2SO_4 + MnSO_4 + Cl_2.$$

4. How much salt is required to make 28 l. of chlorine?

$$2NaCl + MnO_2 + 2H_2SO_4 = 2H_2O + Na_2SO_4 + MnSO_4 + Cl_2.$$

5. How many grams of manganese dioxide are required to make 40 l. of chlorine at 37° C.?

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2.$$

6. What volume of aqueous hydrogen chloride (Δ 1·2) containing 40·8 % by mass of real acid is required to make 3 l. of chlorine?

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2.$$

7. What volume of hydrogen is required to unite with one gm. of chlorine?

$$H + Cl = HCl.$$

8. 10 ccm. of chlorine at 47° C. are mixed with 10 ccm. of hydrogen under 800 mm. and placed in sunlight over water. What volume at 100° C. of which gas remains uncombined?

$$H + Cl = HCl.$$

HYDROGEN CHLORIDE HCl = 36·5.

9. What volume of hydrogen chloride can be obtained from 468 gm. of salt?

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

10. How much salt is required to make 1000 gm. of hydrogen chloride?

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

11. How much salt must be used to make 150 ccm. of hydrogen chloride?

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

12. How many pounds of common salt are required to make 150 lbs. of solution of hydrogen chloride containing 31·5 per cent. of real acid?

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

13. How many kilo. of salt are required to yield 100 kilo. of solution of hydrogen chloride containing 20·22 per cent. of the gas?

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

14. What volume is occupied by 78 gm. of hydrogen chloride?

15. 20 gm. of dilute hydrogen chloride gave 4·53 gm. of silver chloride. What is the percentage of real acid in the solution?

$$HCl + AgNO_3 = HNO_3 + AgCl.$$

16. How many kilograms of pyrolusite containing 80 per cent. of manganese dioxide are required to decompose 400 kilo of hydrogen chloride containing ⅓ of its mass of real acid?

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2.$$

17. 5 gm. of silver chloride are heated in hydrogen. What volume of hydrogen chloride is formed?

$$AgCl + H = HCl + Ag.$$

18. 5·75 gm. of silver nitrate are mixed with an equal mass of solution of hydrogen chloride containing 10·22 per cent. of real acid. How much silver (α) precipitates (β) remains in solution?

$$AgNO_3 + HCl = HNO_3 + AgCl.$$

THE OXYGEN COMPOUNDS OF CHLORINE.

19. What volume of chlorine at 13° C. is required to decompose 40 gm. of mercuric oxide and what volume of chlorine monoxide at 0° C. is formed?

$$2Cl_2 + HgO = HgCl_2 + Cl_2O.$$

20. What volume of chlorine at 39° C. is required to make 1000 gm. of bleaching powder?

$$Cl_2 + CaH_2O_2 = H_2O + CaCl_2O.$$

21. How many litres of chlorine at 13° C. and 720 mm. are required to make 3810 gm. of bleaching powder?

$$Cl_2 + CaH_2O_2 = H_2O + CaCl_2O.$$

22. Find the percentage composition of bleaching powder if its formula be (α) CaO_2Cl_2 (β) $CaOCl_2$ (γ) $Ca_3O_5Cl_4H_6$.

23. The density of chlorine trioxide is found to be 39·7, and that of the tetroxide 33·8. What might these numbers be expected to be?

24. What volume of oxygen and mass of potassium perchlorate is formed on gently heating 245 gm. of potassium chlorate?

$$2KClO_3 = KCl + KClO_4 + O_2.$$

25. How much potassium chlorate is required to make 36·48 l. of oxygen at 15° C. and 750 mm.?

$$2KClO_3 = 2KCl + 3O_2.$$

26. 0·9915 gm. of potassium perchlorate lost 0·457 gm. on heating, and the residue required 0·7683 gm. of silver to precipitate it. 0·3165 gm. of the salt gave 0·201 gm. of potassium sulphate. Find the formula of the salt.

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27. What volume of chlorine at 12° C. and 750 mm. can be obtained from 1170 gm. of salt?

$$2NaCl + MnO_2 + 2H_2SO_4 = 2H_2O + Na_2SO_4 + MnSO_4 + Cl_2.$$

28. 10 gm. of potassium dichromate are heated with hydrogen chloride. What volume of chlorine at 30° C. and 740 mm. is given off?

$$K_2Cr_2O_7 + 14HCl = 7H_2O + 2KCl + Cr_2Cl_6 + 3Cl_2.$$

29. What volume of chlorine will diffuse under the same conditions at 10 ccm. of nitrogen?

30. What volume of chlorine at 20° C. is required to convert 10 gm. of copper leaf into cupric chloride?

$$Cu + Cl_2 = CuCl_2.$$

31. 8·5 ccm. of a saturated solution of hydrogen chloride (containing 500 times its volume of the normal gas) is warmed with twice its volume of hydrogen sulphate. What volume of hydrogen chloride at 20° C. and 780 mm. is evolved?

32. A gram of silver oxide is thrown into hydrogen hypochlorite. What volume of oxygen at 21° C and 770 mm. is evolved?

$$Ag_2O + 2HClO = 2AgCl + H_2O + O_2.$$

33. A solution of 10 gm. of bleaching powder is run into warm hydrogen chloride. What volume of chlorine at 13° C. is given off?

$$CaOCl_2 + 2HCl = CaCl_2 + H_2O + Cl_2.$$

34. A gram of bleaching powder when boiled with cupric oxide gave 80 ccm. of oxygen at 7° C. and 800 mm. Find the percentage of real bleaching powder in the sample.

$$CaOCl_2 = CaCl_2 + O.$$

35. 1·205 gm. of bleaching powder boiled with cupric oxide gave 58·5 ccm. of oxygen measured over water at 13·5° C. The barometer stood at 766 mm. and the water in the tube at 340 mm. Find the percentage of bleaching powder in the sample.

$$CaOCl_2 = CaCl_2 + O.$$

36. A solution of ·8 gm. of ammonio-ferrous sulphate required 20 ccm. of a solution (containing ·01 gm. of bleaching powder in 1 ccm.) to oxidize it. Find the percentage of real bleaching powder in the sample.

$$2(NH_4)_2Fe2SO_46H_2O + CaOCl_2 + H_2SO_4 = CaCl_2 + 13H_2O + 2(NH_4)_2SO_4 + Fe_23SO_4.$$

37. What is the mass of a litre of chloroform ($CHCl_3$) vapour measured at 200° C.?

38. Find the mass of 1·6 l. of carbonyl chloride ($COCl_2$) measured at 26° C. and 730 mm.

39. 50 ccm. of chloroform (Δ 1·5) are run into a hot mixture of potassium dichromate and hydrogen sulphate. What volume of carbonyl chloride at 10° C. and 730 mm. is evolved?

$$2CHCl_3 + 3O = H_2O + Cl_2 + 2COCl_2.$$

40. 10 l. of chlorine at 15° C. are passed into a warm mixture of carbon disulphide and antimonic chloride. How much carbon tetrachloride is formed?

$$4Cl_2 + CS_2 = 2SCl_2 + CCl_4.$$

CHAPTER XII.

BROMINE Br = 80.

1. Sea-water contains 0·007 per cent. of magnesium bromide ($MgBr_2$). What weight of it is required to obtain a litre of bromine (Δ 3)?

2. How much potassium bromide is required to prepare 10 gm. of bromine?

$$2KBr + MnO_2 + 2H_2SO_4 = 2H_2O + K_2SO_4 + MnSO_4 + Br_2.$$

3. How many ccm. does a pound of bromine (Δ 3) occupy?

4. Find the percentage composition of bromine hydrate ($Br_2 10H_2O$).

5. 100 gm. of water dissolve 3 gm. of bromine. If the solution be dropped into a red-hot retort, what volume of oxygen at 13° C. is set free?

$$Br_2 + H_2O = 2HBr + O.$$

6. 9 gm. of potassium bromide are distilled with hydrogen phosphate. What volume of gaseous hydrogen bromide at 26° C. is evolved?

$$KBr + HPO_3 = KPO_3 + HBr.$$

7. 70 gm. of bromine are dissolved in water. What volume of hydrogen sulphide at 15° C. is required to convert them into hydrogen bromide?

$$Br_2 + H_2S = S + 2HBr.$$

8. How much phosphorus and what volume of bromine (Δ 3) is required to make 10 l. of hydrogen bromide?

$$P + 3Br + 3H_2O = H_3PO_3 + 3HBr.$$

9. 10 gm. of phosphorus tribromide are decomposed by water, and silver nitrate is added. How much silver bromide precipitates?

$$PBr_3 + 3H_2O + 3AgNO_3 = H_3PO_3 + 3HNO_3 + 3AgBr.$$

10. How many grams of bromine are there in a litre of gaseous hydrogen bromide (HBr).

11. Find the mass of 127 ccm. of gaseous hydrogen bromide.

12. Hydrogen bromide is 2·8 times heavier than air. What is its molecular weight?

13. The strongest solution of hydrogen bromide (HBr Δ 1·515) contains half its mass of real acid. How much bromine is there in a litre of the solution?

14. De Marignac found that 3·946 gm. of silver dissolved in hydrogen nitrate were precipitated by 4·353 gm. of potassium bromide. What is the atomic weight of bromine?

$$AgNO_3 + KBr = KNO_3 + AgBr.$$

15. Calculate the percentage composition of silver bromide AgBr.

16. How much potassium (α) bromide (β) bromate is formed on adding 520 gm. of bromine to a solution of potassium hydrate?

$$6Br + 6HKO = 3H_2O + 5KBr + KBrO_3.$$

17. 10 gm. of potassium bromate are heated. What volume of oxygen at 13° C. is given off?

$$KBrO_3 = KBr + O_3.$$

18. A spherical glass bulb is to contain 10 gm. of bromine (Δ 3). What must the internal radius be?

CHAPTER XIII.

IODINE, I = 127.

1. How much ferric chloride is required to obtain the iodine from 100 tonnes of kelp, each tonne of which contains 4·07 kilo. of iodine?

$$2NaI + Fe_2Cl_6 = 2NaCl + 2FeCl_2 + I_2.$$

2. How much "manganese" containing 60 per cent. of real dioxide is required to liberate the iodine from 100 gm. of potassium iodide?

$$2KI + MnO_2 + 2H_2SO_4 = 2H_2O + K_2SO_4 + MnSO_4 + I_2.$$

3. How much potassium iodide is required to prepare 63·5 gm. of iodine?

$$2KI + MnO_2 + 2H_2SO_4 = 2H_2O + K_2SO_4 + MnSO_4 + I_2.$$

4. How much iodine is liberated from potassium iodide by the chlorine evolved on boiling 6 gm. of manganese dioxide with hydrogen chloride?

$$MnO_2 + 4HCl = 2H_2O + MnCl_2 + Cl_2.$$
$$2KI + Cl_2 = 2KCl + I_2.$$

5. 0·1 gm. of potassium dichromate is distilled with hydrogen chloride. How much iodine will the evolved chlorine set free from potassium iodide?

$$K_2Cr_2O_7 + 14HCl = 7H_2O + 2KCl + Cr_2Cl_6 + 3Cl_2.$$
$$6KI + 3Cl_2 = 6KCl + 3I_2.$$

6. Iodine vapour is 8·716 times as heavy as air. Find its molecular weight.

7. How many times is solid iodine (Δ 4·94) heavier than an equal volume of its vapour measured at 350° C.?

8. 3·81 gm. of iodine vapour mixed with hydrogen are passed through a red-hot tube. What volume of hydrogen iodide is formed?

$$H + I = HI.$$

9. What volume of hydrogen sulphide must be passed into how much iodine suspended in 80 ccm. of water to make a 20 per cent. solution of hydrogen iodide?

$$H_2S + I_2 = S + 2HI.$$

10. 20 gm. iodine are suspended in water. What volume of hydrogen sulphide at 15° C. is required to convert them into hydrogen iodide?

$$H_2S + I_2 = S + 2HI.$$

11. How much iodine, phosphorus, and potassium iodide must be used to make 10 l. of gaseous hydrogen iodide at 15° C.?

$$10I_2 + 4P + 8KI + 16H_2O = 4K_2HPO_4 + 28HI.$$

12. Find the percentage composition of iodine (α) pentoxide I_2O_5, (β) septoxide I_2O_7, and of hydrogen (γ) iodate HIO_3, (δ) periodate HIO_4.

13. What mass of hydrogen is there in a litre of hydrogen (α) bromide HBr, (β) iodide HI?

14. How much iodine is there in a litre of a solution (Δ 1·7) containing 52 per cent. of hydrogen iodide (HI)?

15. 119 gm. of iodine are suspended in water. What volume of chlorine is required to convert them into hydrogen iodate?

$$I + 5Cl + 3H_2O = 5HCl + HIO_3.$$

16. How much iodine and potassium chlorate are required to make a kilo. of hydrogen iodate?

$$10KClO_3 + 12I + 6H_2O = 10KCl + 12HIO_3.$$

17. 14 gm. of potassium iodate are heated. What volume of oxygen at 13° C. is evolved?

$$KIO_3 = KI + O_3.$$

18. 8 gm. of silver iodate are heated. What volume of oxygen at 18° C. and 720 mm. is evolved?

$$AgIO_3 = AgI + O_3.$$

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19. How much phosphorus and iodine must be used to make 100 l. of hydrogen iodide at 30° C. and 740 mm?

$$P + 3I + 3H_2O = H_3PO_3 + 3HI.$$

20. How much iodine must be thrown into a balloon containing 5 l. of chlorine at 20° C. and 780 mm. to obtain the monochloride?

$$I + Cl = ICl.$$

21. Find the percentage composition of iodoform (CHI_3).

22. A mixture of silver chloride, bromide, and iodide weighed 15·57 gm. After heating with bromine water the silver chloride weighed 14·69 gm. And after heating with chlorine water the silver chloride weighed 12·2 gm. How much chlorine, bromine, and iodine were present in the mixture?

CHAPTER XIV.

FLUORINE, F = 19.

1. What is the percentage composition of (α) fluorspar CaF_2, (β) cryolite $Na_6Al_2F_{12}$?

2. 100 gm. of fluorspar are heated with hydrogen sulphate. How much calcium sulphate and hydrogen fluoride is formed?

$$CaF_2 + H_2SO_4 = CaSO_4 + 2HF.$$

3. How much platinum tetrafluoride must be heated to give 100 cem. of fluorine at 10° C. ?

$$PtF_4 = Pt + 2F_2.$$

4. What volume of hydrogen fluoride at 39° C. can be obtained from 50 gm. of sodium fluoride ?

$$2NaF + H_2SO_4 = Na_2SO_4 + 2HF.$$

5. What volume of hydrogen fluoride at 20° C. can be obtained from 20 gm. of cryolite ?

$$Na_6Al_2F_{12} + 6H_2SO_4 = 3Na_2SO_4 + Al_23SO_4 + 12HF.$$

6. What volume of anhydrous hydrogen fluoride (Δ 0·9879) can be obtained from a kilo. of potassium and hydrogen fluoride ?

$$HKF_2 = KF + HF.$$

7. 150 ccm. of hydrogen fluoride are passed over heated sodium. How much sodium fluoride is formed ?

$$HF + Na = NaF + H.$$

8. 3·2617 gm. of calcium fluoride gave 5·6867 gm. of calcium sulphate. What is the atomic weight of fluorine ?

$$CaF_2 + H_2SO_4 = CaSO_4 + 2HF.$$

9. How much silica and hydrogen fluosilicate are produced by passing the gas evolved on heating 468 gm. of fluorspar with sand and hydrogen sulphate into water ?

$$2CaF_2 + SiO_2 + 2H_2SO_4 = 2CaSO_4 + 2H_2O + SiF_4.$$
$$3SiF_4 + 2H_2O = SiO_2 + 2H_2SiF_6.$$

10. What volume of silicon fluoride at 15° C. is evolved on heating 1 gm. of fluorspar with sand and hydrogen sulphate ?

$$2CaF_2 + SiO_2 + 2H_2SO_4 = 2CaSO_4 + 2H_2O + SiF_4.$$

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11. Find the mass of 10 l. of hydrogen fluoride (H_2F_2) at 30° C. and 740 mm.

12. If 100 gm. of commercial hydrogen fluoride containing 35 per cent. of real acid be heated with excess of hydrogen sulphate, what volume of gas (H_2F_2) at 20° C. and 750 mm. is evolved ?

13. A balloon holding 4394·7 ccm., when filled with gaseous hydrogen fluoride at 30° C. and 745 mm., weighed 428·255 gm.; and when vacuous weighed 421·436 gm. Find the density of hydrogen fluoride.

14. Find the percentage composition of carbon tetrafluoride CF_4.

CHAPTER XV.

SULPHUR, S = 32.

1. Find the percentage composition of (α) galena PbS, (β) zinc blende ZnS.

2. Find the formulæ of substances containing (α) copper 34·5 per cent., iron 30·5 per cent., and sulphur 35 per cent., (β) calcium 29·4 per cent., sulphur 23·6 per cent., and oxygen 47 per cent.

3. What volume is occupied by 1000 gm. of (α) common sulphur (Δ 2·05) and (β) plastic sulphur (Δ 1·957)?

4. How much does a stick of brimstone (Δ 2) 1 m. long and 4 cm. in diameter weigh?

5. What volume is occupied by 100 gm. of sulphur vapour (S_6) at 400° C.?

6. By heating 10,000 grains of silver in sulphur vapour, Dumas obtained 11481·5 grains of silver sulphide. Find the atomic weight of sulphur.

$$Ag_2 + S = Ag_2S.$$

7. What volume of air is required to burn 1000 gm. of sulphur?

$$S + O_2 = SO_2.$$

8. How many grams of sulphur can be burnt in a globe 5 decimetres across filled with oxygen at 17° C.?

$$S + O_2 = SO_2.$$

SULPHUR DIOXIDE, SO_2 = 64.

9. 20 gm. of sulphur are burnt in oxygen. What volume of sulphur dioxide is formed?

$$S + O_2 = SO_2.$$

10. How much sulphur must be burnt to make 10 l. of sulphur dioxide?

$$S + O_2 = SO_2.$$

11. How much copper and hydrogen sulphate are required to make 1000 gm. of sulphur dioxide?

$$Cu + 2H_2SO_4 = CuSO_4 + 2H_2O + SO_2.$$

12. What volume of sulphur dioxide is obtained on heating 20 gm. of mercury with hydrogen sulphate?

$$Hg + 2H_2SO_4 = HgSO_4 + 2H_2O + SO_2.$$

13. 50 ccm. of sulphur (Δ 2) are burnt. What volume of sulphur dioxide at 14° C. and 780 mm. is formed?

$$S + O_2 = SO_2.$$

14. What volume of sulphur dioxide at 20° C. and 740 mm. is obtained by the action of 20 gm. of hydrogen sulphate upon copper?

$$Cu + 2H_2SO_4 = CuSO_4 + 2H_2O + SO_2.$$

15. How much copper must be dissolved in hydrogen sulphate to make 10 l. of sulphur dioxide at 18° C.?

$$Cu + 2H_2SO_4 = CuSO_4 + 2H_2O + SO_2.$$

16. What volume is occupied by 19·2 gm. of sulphur dioxide?

17. What volume of sulphur dioxide is required to neutralize 100 gm. of potassium hydrate?

$$2HKO + SO_2 = H_2O + K_2SO_3.$$

18. How much sulphur is there in a litre of sulphur dioxide measured at 39° C. and 720 mm.?

19. A litre of sulphur dioxide is found to weigh 2·8672 gm. What is its molecular weight?

20. 16 ccm. of hydrogen diffuse in 100 seconds. What volume of sulphur dioxide will diffuse under the same conditions?

21. Find the percentage composition of sodium thiosulphate ($Na_2S_2O_3.5H_2O$).

22. How much iodine is required to oxidize a gram of sodium thiosulphate, and how much sodium tetrathionate is formed?

$$2Na_2S_2O_35H_2O + I_2 = 2NaI + 10H_2O + Na_2S_4O_6.$$

HYDROGEN SULPHATE, $H_2SO_4 = 98$.

23. How much hydrogen sulphate can be made from 102·4 gm. of sulphur?

$$S + 3O + H_2O = H_2SO_4.$$

24. How much hydrogen sulphate can be obtained from a ton of ferrous disulphide (iron pyrites)?

$$2FeS_2 + 4H_2O + 15O = Fe_2O_3 + 4H_2SO_4.$$

25. How many cwt. of sulphur are required to make a ton of brown oil of vitriol containing 70 per cent. of real acid?

$$S + H_2O + 3O = H_2SO_4.$$

26. What volume of hydrogen sulphate (Δ 1·84) can be obtained from 1000 kilo. of iron pyrites?

$$2FeS_2 + 4H_2O + 15O = Fe_2O_3 + 4H_2SO_4.$$

27. How much oil of vitriol containing 70 per cent. of real acid can be made from 250 kilo. of pyrites containing 42 per cent. of sulphur?

$$S + 3O + H_2O = H_2SO_4.$$

28. How many tons of pyrites containing 42 per cent. of sulphur are required to make 200 tons of oil of vitriol containing 70 per cent. of real acid?

$$S + 3O + H_2O = H_2SO_4.$$

29. How many grains does a cubic inch of hydrogen sulphate (Δ 1·84) weigh?

30. How much sulphur is there in a litre of hydrogen sulphate (Δ 1·84)?

31. How many kilo. of hydrogen sulphate (Δ 1·84) will a tank 1 m. by 2 m. by 3 m. hold?

32. A tank of hydrogen sulphate (Δ 1·84) is 10 ft. long and 5 ft. wide and deep. How many tonnes of acid will it hold?

33. Find the percentage composition of chamber crystals SO_2NO_2HO.

34. A body contains hydrogen 1·12 per cent., sulphur 35·9 per cent., and oxygen 62·98 per cent. Find the formula and name of it.

35. The vapour of hydrogen sulphate is 1·697 times as heavy as air. What is its apparent molecular weight?

36. The vapour of 10 gm. of hydrogen sulphate occupies what volume at 400° C.?

37. Sulphur trioxide is passed over 187 gm. of barium oxide heated in a tube. How much barium sulphate is formed?

$$SO_3 + BaO = BaSO_4.$$

38. 5 ccm. of dilute hydrogen sulphate are neutralized by 18·8 ccm. of a solution of sodium carbonate containing 106 gm. of the dry salt per litre. What volume of hydrogen sulphate (Δ 1·84) is there in a litre of the dilute acid?

$$Na_2CO_3 + H_2SO_4 = Na_2SO_4 + H_2O + CO_2.$$

39. How much colcothar and Nordhausen acid can be made from 348 tons of green vitriol?

$$6FeSO_47H_2O + 3O = 39H_2O + 3Fe_2O_3 + 3H_2S_2O_7.$$

40. 4 l. of sulphur dioxide at 13° C. mixed with oxygen are passed over a heated mixture of cupric and chromic oxides. How much sulphur trioxide is formed ?

$$SO_2 + O = SO_3.$$

41. If 100 gm. of lead form 146·45 gm. of lead sulphate, what is the molecular weight of hydrogen sulphate ?

$$Pb2NO_3 + H_2SO_4 = 2HNO_3 + PbSO_4.$$

42. 10 gm. of hydrogen sulphate are heated with phosphorus pentachloride. What volume will the sulphuryl dichloride occupy at 350° C. ?

$$H_2SO_4 + 2PCl_5 = 2POCl_3 + 2HCl + SO_2Cl_2.$$

HYDROGEN SULPHIDE, $H_2S = 34$.

43. 20 gm. of sulphur are heated in hydrogen. What volume of hydrogen sulphide at 30° C. is formed ?

$$H_2 + S = H_2S.$$

44. What volume of hydrogen sulphide is evolved on dissolving 10 gm. of ferrous sulphide in hydrogen chloride ?

$$FeS + 2HCl = FeCl_2 + H_2S.$$

45. How much ferrous sulphide must be dissolved in acid to make 100 l. of hydrogen sulphide ?

$$FeS + 2HCl = FeCl_2 + H_2S.$$

46. What volume of hydrogen sulphide at 15° C. and 770 mm. is evolved on dissolving 44 gm. of ferrous sulphide in acid ?

$$FeS + H_2SO_4 = FeSO_4 + H_2S.$$

47. 100 gm. of sulphur are heated with tallow. What volume of hydrogen sulphide at 17° C. and 800 mm. is evolved ?

$$S + H_2 = H_2S.$$

48. 390 gm. of antimony sulphide are dissolved in hot hydrogen chloride. What volume of hydrogen sulphide at 30° C. is given off ?

$$Sb_2S_3 + 6HCl = 2SbCl_3 + 3H_2S.$$

49. What volume of hydrogen sulphide at 15° C. is evolved on dissolving 134 gm. of antimony sulphide in hot hydrogen chloride ?

$$Sb_2S_3 + 6HCl = 2SbCl_3 + 3H_2S.$$

50. What is the density of hydrogen sulphide referred to air?

51. How many grams of sulphur are there in 600 ccm. of hydrogen sulphide?

52. What volume of air is required to burn 1 l. of hydrogen sulphide?

$$H_2S + 3O = H_2O + SO_2.$$

53. What volume of hydrogen sulphide will diffuse under the same conditions as 10 ccm. of oxygen?

54. 2 l. of hydrogen sulphide and 1 l. of sulphur dioxide, both at 0° C. are passed through a red-hot tube. What volumes of sulphur and steam at 1000° C. are formed?

$$2H_2S + SO_2 = 2H_2O + 3S.$$

55. A gram of calcium sulphate is strongly heated with charcoal, and the resulting sulphide is dissolved in acid. What volume of hydrogen sulphide at 13° C. is evolved?

$$CaSO_4 + 4C = 4CO + CaS.$$
$$CaS + 2HCl = CaCl_2 + H_2S.$$

56. How much (α) lead sulphide, (β) mercury sulphide can be thrown down by 500 ccm. of hydrogen sulphide at 14° C.?

$$[HgPb]2NO_3 + H_2S = 2HNO_3 + [HgPb]S.$$

Carbon Disulphide, $CS_2 = 76$.

57. What volume of carbon disulphide (Δ 1·27) can be made by the action of a kilo. of sulphur upon hot charcoal?

$$C + S_2 = CS_2.$$

58. What volume of nitric oxide is required to burn 2 ccm. of carbon disulphide (Δ 1·27)?

$$CS_2 + 6NO = 6N + CO_2 + 2SO_2.$$

59. 1 ccm. of carbon disulphide (Δ 1·27) is heated. What does the vapour measure at 350° C. and 600 mm.?

60. 10 ccm. of carbon disulphide (Δ 1·27) are burnt in oxygen. What volumes of carbon dioxide and of sulphur dioxide at 17° C. and 800 mm. are formed?

$$CS_2 + 6O = CO_2 + 2SO_2.$$

61. The vapour of carbon disulphide is passed over 20 gm. of chromic oxide heated with charcoal. How much chromic sulphide is formed?

$$2Cr_2O_3 + 3CS_2 + 3C = 6CO + 2Cr_2S_3.$$

62. What volume of chlorine at 15° C. and 720 mm. must be passed into excess of melted sulphur to make 245 gm. of sulphur chloride?

$$Cl_2 + S_2 = S_2Cl_2.$$

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63. What is the mass of 4 l. of carbon oxysulphide (COS) at 30° C.?

64. 100 gm. of mercury are heated with hydrogen sulphate. What volume of sulphur dioxide at 30° C. and 800 mm. is evolved?

$$Hg + 2H_2SO_4 = HgSO_4 + 2H_2O + SO_2.$$

65. To make 1000 kilo. of hydrogen sulphate, how much pyrites, what volume of air at 15° C., and of steam at 300° C. is required?

$$2FeS_2 + 4H_2O + 15O = Fe_2O_3 + 4H_2SO_4.$$

66. A cubic decimetre of ferrous sulphide (Δ 4·4) is dissolved in dilute acid. What volume of hydrogen sulphide at 17° C. and 770 mm. is evolved?

$$FeS + 2HCl = FeCl_2 + H_2S.$$

67. What volume of carbon disulphide (Δ 1·27) must be burnt to give 10 l. of sulphur dioxide at 15° C. and 750 mm.?

$$CS_2 + 3O_2 = CO_2 + 2SO_2.$$

68. A room 5 m. by 4 m. by 5 m., the air of which contains 20 per cent. by volume of available oxygen, is to be disinfected. What volume of carbon disulphide (Δ 1·27) can be burnt in it?

$$CS_2 + 3O_2 = CO_2 + 2SO_2.$$

CHAPTER XVI.

BORON, B = 11.

1. Find the percentage composition of borax ($Na_2B_4O_7 10H_2O$).

2. Find the percentage composition of boron and nitryl chloride ($BNOCl_4$).

3. Find the formulæ of substances containing (α) boron 31·19 and oxygen 68·81 per cent., (β) silicon 47 and oxygen 53 per cent.

4. Boron trichloride is 4·07 times as heavy as air. What is its molecular weight?

5. How many grams do 200 ccm. of boron trichloride (BCl_3) at 97° C. and 720 mm. weigh?

6. What volume of boron trichloride at 210° C. can be made from 390 gm. of boron trioxide?

$$B_2O_3 + 6Cl + 3C = 3CO + 2BCl_3.$$

7. What volume of nitrogen at 15° C. is absorbed in converting 4·4 gm. of boron into the nitride?

$$B + N = BN.$$

8. 7 gm. of boron nitride are heated in a current of steam. What volume of ammonia at 13° C. is given off?

$$2BN + 3H_2O = B_2O_3 + 2NH_3.$$

9. 10 gm. of boron sulphide are heated in steam. What volume of hydrogen sulphide at 21° C. is formed?

$$B_2S_3 + 3H_2O = B_2O_3 + 3H_2S.$$

10. Crystallized hydrogen borate when heated to 100° C. loses 21·8 per cent. of water, and when heated to 160° C. it loses 14·5 per cent. more. Find the formulæ of the bodies formed.

$$(B_2O_3)_n(H_2O)_{3n} = (B_2O_3)_n(H_2O)_{3n-x} + (H_2O)_x.$$

11. 90 gm. of fluorspar are heated with boron trioxide and hydrogen sulphate. What volume of boron trifluoride at 15° C. is formed?

$$3CaF_2 + B_2O_3 + 3H_2SO_4 = 3CaSO_4 + 3H_2O + 2BF_3.$$

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12. How much does a litre of boron trifluoride (BF_3) measured at 50° C. and 1000 mm. weigh?

13. What volume of gaseous ammonia at 10° C. is required to convert 10 gm. of boron into the nitride?

$$2B + 2NH_3 = 3H_2 + 2BN.$$

14. Find the formula of a substance containing nitrogen 14·68, hydrogen 3·15, boron 7·69, and chlorine 74·47 per cent.

CHAPTER XVII.

SILICON, Si = 28·4.

1. How much silicon can be obtained from 119 gm. of potassium silicofluoride?

$$K_2SiF_6 + 4K = 6KF + Si.$$

2. Find the percentage composition of barium silicofluoride ($BaSiF_6$).

3. What is the percentage composition of Willemite (Zn_2SiO_4)?

4. Two litres of the vapour of silicon chloride at 117° C. are passed over heated sodium. How much silicon is set free?

$$SiCl_4 + 4Na = 4NaCl + Si.$$

5. According to Schiel 0·6738 gm. of silicon tetrachloride, after decomposition by ammonia, gave 2·277 gm. of silver chloride. Find the atomic weight of silicon.

$$2H_2O + 4NH_3 + SiCl_4 + 4AgNO_3 = 4NH_4NO_3 + SiO_2 + 4AgCl.$$

6. What is the percentage composition of steatite ($Mg_3Si_4O_{11}H_2O$)?

7. Find the formula of a substance containing silicon 26·27, calcium 18·43, magnesium 11·06, and oxygen 44·24 per cent.

8. The rock-crystal (Δ 2·605) standard pound is a cube. How many inches does it measure along each edge?

9. Find the formula of Wollastonite, which contains silica 51·31, alumina 1·37, lime 45·66, and magnesia 0·73 per cent.

10. What is the formula of allophane, which consists of silica 23·53, alumina 37·73, lime 1·92, and water 36·86 per cent.?

11. Find the formula of a substance containing magnesium 22·02, silicon 25·69, oxygen 44·04, and water 8·25 per cent.

12. 20 gm. of silica are heated in the vapour of carbon disulphide. How much silicon sulphide and what volume of carbon dioxide at 13° C. is formed?

$$SiO_2 + CS_2 = SiS_2 + CO_2.$$

13. How much do 500 ccm. of hydrogen silicide (SiH_4) at 13° C. and 720 mm. weigh?

14. How much silica is formed on burning 2 l. of hydrogen silicide at 30° C.?

$$SiH_4 + 4O = 2H_2O + SiO_2.$$

15. Ten grams of silica are heated with fluorspar and hydrogen sulphate. What volume of silicon fluoride at 13° C. is formed?

$$SiO_2 + 2CaF_2 + 2H_2SO_4 = 2CaSO_4 + 2H_2O + SiF_4.$$

16. What volume is occupied by 20·8 gm. of silicon fluoride at 60° C.? And how much hydrogen silicofluoride is formed if the gas be passed into water?

$$3SiF_4 + 2H_2O = SiO_2 + 2H_2SiF_6.$$

17. What volume of chlorine at 26° C. and mass of carbon is required to make 100 gm. of silicon tetrachloride?

$$SiO_2 + 2C + Cl_4 = 2CO + SiCl_4.$$

18. The vapour of silicon chloride is 5·939 times as heavy as air, and that of silicon fluoride 3·6 times as heavy as air. Find the double densities referred to hydrogen.

19. How much does a litre of silicon tetrachloride ($SiCl_4$) at 200° C. weigh?

20. What is the mass of 450 ccm. of the vapour of silicon bromide ($SiBr_4$) at 350° C. and 400 mm.?

Find the formulæ of the following minerals containing:—

21. Sahlite, silica 54·02, lime 24·88, ferrous oxide 8·07, and magnesia 13·52 per cent.

22. Skolezite, silica 46·2, alumina 26·28, lime 9·22, sodium oxide 5·16, and water (low) 13·25 per cent.

23. Topaz, alumina 58·28, silica 34·01, and fluorine 7·6 per cent.

24. Thomsonite, sodium oxide 4·53, lime 13·54, alumina 30·7, silica 38·3, and water 13 per cent.

25. Iölite, magnesia 10·45, ferrous oxide 5, alumina 32·88, silica 49·95, water and loss 1·75 per cent.

26. Orthoclase, silica 65·37, alumina 18·74, ferric oxide 0·13, lime 0·27, potassium oxide 12·98, and sodium oxide 2·48 per cent.

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27. What is the percentage composition of triethyl silicoformate $HSiO_3(C_2H_5)_3$?

28. What volume of hydrogen silicide at 15° C. and 740 mm. can be obtained from 20 gm. of triethyl silicoformate?

$$4SiH(C_2H_5O)_3 = SiH_4 + 3Si(C_2H_5O)_4.$$

29. What does a litre of silicon chloroform ($SiHCl_3$) at 180° C. weigh?

30. Find the mass in grams of a sphere of rock-crystal (Δ 2·61) 1 decimetre in diameter.

CHAPTER XVIII.

PHOSPHORUS, P = 31.

1. How much phosphorus is there in 700 gm. of bone-ash (Ca_32PO_4)?

2. How much phosphorus is there in 120 kilo. of bone-ash containing 85 per cent. of calcium phosphate (Ca_32PO_4)?

3. The skeleton of a man weighs 24 lb. and contains 58 per cent. of calcium phosphate (Ca_32PO_4). Find the amount of phosphorus present.

4. Phosphorus appears to exist in bone-ash as $CaCO_33Ca_32PO_4$. Find the percentage composition of this substance.

5. How much bone-ash containing 87 per cent. of calcium phosphate is required to make 200 kilo. of superphosphate of lime?

$$Ca_32PO_4 + 2H_2SO_4 = 2CaSO_4 + CaH_42PO_4.$$

6. How many kilograms of bone-ash containing 85 per cent. of calcium phosphate are required to make 2 tons of superphosphate of lime?

$$Ca_32PO_4 + 2H_2SO_4 = 2CaSO_4 + CaH_42PO_4.$$

7. How much calcium metaphosphate is obtained on heating 100 lb. of superphosphate of lime?

$$CaH_42PO_4 = 2H_2O + Ca2PO_3.$$

8. How much carbon and silica must be distilled with 39·6 lb. of calcium metaphosphate, and how much phosphorus should be obtained?

$$Ca2PO_3 + 5C + SiO_2 = CaSiO_3 + 5CO + 2P.$$

9. How much phosphorus is obtained on heating 100 kilo. of calcium metaphosphate with carbon?

$$2Ca2PO_3 + 5C = 5CO + Ca_2P_2O_7 + 2P.$$

10. Find the mass of a round stick of phosphorus (Δ 1·83) 1 decimetre long and 2 cm. across.

11. 100 l. of yellow (Δ 1·83) are converted into red (Δ 2·14) phosphorus. What is the volume of the latter variety?

12. What is the mass of 1·234 l. of phosphorus vapour (P_4) at 500° C.?

13. Phosphorus vapour is 4·42 times as heavy as air. What is its molecular weight?

14. What volume of air is required to burn 248 gm. of phosphorus?

$$P_2 + O_5 = P_2O_5.$$

15. What is the mass of a ball of phosphorus (Δ 1·83) 1 cm. in diameter?

16. A gram of phosphorus when burnt gives 2·29 gm. of phosphorus pentoxide. What is the atomic weight of phosphorus?

$$P_2 + O_5 = P_2O_5.$$

PHOSPHORUS TRIOXIDE, $P_2O_3 = 110$.
HYDROGEN PHOSPHITE, $H_3PO_3 = 82$.

17. How much phosphorus must be burnt to form 46 gm. of phosphorus trioxide?

$$P_2 + O_3 = P_2O_3.$$

18. What volume of chlorine at 15° C. must be passed into 100 gm. of phosphorus melted under water to convert them into hydrogen phosphite?

$$3Cl + P + 3H_2O = 3HCl + H_3PO_3.$$

19. What volume of hydrogen phosphide is evolved on boiling 10 gm. of (α) hydrogen phosphite, (β) hydrogen hypophosphite?

$$4H_3PO_3 = H_3P + 3H_3PO_4.$$
$$2H_3PO_2 = H_3P + H_3PO_4.$$

20. How much sodium hypophosphite can be obtained by boiling 20 gm. of phosphorus with sodium hydrate, and what volume of phosphine is given off?

$$P_4 + 3HNaO + 3H_2O = 3NaPH_2O_2 + PH_3.$$

PHOSPHORUS PENTOXIDE, $P_2O_5 = 142$.
HYDROGEN PHOSPHATE, $H_3PO_4 = 98$.

21. How much phosphorus must be burnt to form 46·86 gm. of phosphorus pentoxide?

$$P_2 + O_5 = P_2O_5.$$

22. How much water must be added to 187 gm. of phosphorus pentoxide to convert it into hydrogen (α) orthophosphate, (β) pyrophosphate, (γ) metaphosphate?

$$P_2O_5 + 3H_2O = 2H_3PO_4.$$
$$P_2O_5 + 2H_2O = H_4P_2O_7.$$
$$P_2O_5 + H_2O = 2HPO_3.$$

23. 9 gm. of phosphorus pentoxide absorb 2·76 gm. of moisture from the air. Find a formula for the body formed.

24. How much hydrogen orthophosphate is obtained on heating 1796 gm. of phosphorus with hydrogen nitrate?

$$2P + 5O + 3H_2O = 2H_3PO_4.$$

25. Find the formula of a substance containing calcium 38·72, phosphorus 20, and oxygen 41·28 per cent.

26. Calculate the percentage composition of the three silver phosphates (α) Ag_3PO_4, (β) $Ag_4P_2O_7$, (γ) $AgPO_3$.

27. Find the percentage composition of (α) common sodium phosphate $Na_2HPO_4.12H_2O$, (β) microcosmic salt $Na(NH_4)HPO_4.4H_2O$.

28. What volume of hydrogen sulphide at 15° C. is required to decompose 100 gm. of lead pyrophosphate?

$$Pb_2P_2O_7 + 2H_2S = 2PbS + H_4P_2O_7.$$

29. 20 gm. of hydrogen metaphosphate are boiled with water. How much orthophosphate is formed?

$$HPO_3 + H_2O = H_3PO_4.$$

30. 100 gm. of phosphorus are melted under water. What volume of chlorine at 17° C. is required to convert them into hydrogen orthophosphate?

$$2P + 5Cl_2 + 8H_2O = 10HCl + 2H_3PO_4.$$

PHOSPHINE, $PH_3 = 34$.

31. 79 gm. of hydrogen phosphite are heated. What volume of phosphine is evolved?

$$4H_3PO_3 = H_3P + 3H_3PO_4.$$

32. 10 gm. of phosphorus are boiled with potassium hydrate. What volume of phosphine at 37° C. is evolved?

$$4P + 3HKO + 3H_2O = 3KPH_2O_2 + PH_3.$$

33. 5 gm. of phosphorus are boiled with baryta water. What volume of phosphine at 15° C. is given off?

$$2P_4 + 3BaH_2O_2 + 6H_2O = 3Ba(PH_2O_2)_2 + 2PH_3.$$

34. 10 ccm. of phosphorus (Δ 1·77) are dissolved in barium hydrate? What volume of phosphine at 21° C. and 531 mm. is given off?

$$3BaH_2O_2 + 6H_2O + 2P_4 = 3Ba(PH_2O_2)_2 + 2PH_3.$$

35. 7·29 gm. of phosphonium iodide when heated with potassium hydrate give how many litres of phosphine at 30° C. ?

$$PH_4I + KHO = KI + H_2O + PH_3.$$

36. How much phosphorus is there in a litre of phosphine at 12° C. ?

37. Find the formula of a substance containing phosphorus 98·41 and hydrogen 1·59 per cent.

38. Hydrogen phosphide is 1·184 times as heavy as air. What is its molecular weight ?

39. What volume of air is required to burn 179 ccm. of phosphine, and how much phosphorus pentoxide is formed ?

$$2PH_3 + 8O = 3H_2O + P_2O_5.$$

40. What volume of phosphine will diffuse under the same conditions as 100 ccm. of hydrogen ?

THE HALOGEN COMPOUNDS OF PHOSPHORUS.

41. 100 gm. of calcium phosphate are mixed with charcoal and heated in chlorine and carbon monoxide. What volume of chlorine at 15° C. is required, and what volume of liquid phosphorus oxychloride (Δ 1·7) is formed ?

$$Ca_32PO_4 + 6CO + 12Cl = 3CaCl_2 + 6CO_2 + 2POCl_3.$$

42. How much crystallized hydrogen oxalate must be heated with a kilogram of phosphorus pentachloride to convert it into the oxychloride ?

$$3PCl_5 + C_2H_2O_4.2H_2O = 6HCl + CO + CO_2 + 3POCl_3.$$

43. Find the formula of a substance containing phosphorus 24·61, oxygen 19·05, and chlorine 56·37 per cent.

44. The vapour of phosphorus oxychloride is 5·3 times as heavy as air. What is its molecular weight ?

45. How much does a litre of the vapour of phosphorus oxychloride ($POCl_3$) measured at 300° C. weigh ?

46. A litre of phosphorus oxychloride (Δ 1·7) is distilled through red-hot charcoal. What volume of phosphorus trichloride (Δ 1·6) is formed ?

$$POCl_3 + C = CO + PCl_3.$$

47. What volume of chlorine at 20° C. must be passed into a kilogram of melted phosphorus to convert it into the trichloride ?

$$P + Cl_3 = PCl_3.$$

48. What volume of chlorine at 21° C. must be passed into 100 gm. of phosphorus trichloride to convert them into the pentachloride?

$$PCl_3 + Cl_2 = PCl_5.$$

49. The vapour of phosphorus trichloride is 4·742 times as heavy as air; what is its molecular weight?

50. What volume of chlorine at 30° C. must be passed into a solution of 476 gm. of phosphorus in carbon disulphide to convert it into pentachloride?

$$P + 5Cl = PCl_5.$$

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51. Find the percentage composition of sodium α-phosphate ($Na_6P_4O_{13}$).

52. Find a formula for lazulite which contains phosphorus pentoxide 43·76, alumina 31·7, magnesia 10·04, ferrous oxide 8·17, and water 5·59 per cent.

53. How much phosphorus is contained in 4·3 l. of phosphine (PH_3) measured at 22° C. and 730 mm.?

54. What volume of hydrogen bromide at 210° C. is evolved on boiling 20 gm. of phosphorus pentabromide with water?

$$PBr_5 + 4H_2O = H_3PO_4 + 5HBr.$$

55. What volume of hydrogen sulphide at 30° C. will react with 100 gm. of phosphorus pentachloride?

$$PCl_5 + H_2S = 2HCl + PSCl_3.$$

56. What volume of vapour at 300° C. and 740 mm. is formed by 13 gm. of phosphorus trichloride (PCl_3)?

57. The vapour of phosphorus pentachloride is 3·65 times as heavy as air. What is its apparent molecular weight?

58. A globe holding 500 ccm. is filled with the vapour of phosphorus pentachloride (PCl_5) at 350° C. and 755 mm. What is the mass of the vapour?

CHAPTER XIX.

ARSENIC, As = 75.

1. How much charcoal is required to reduce a kilo. of arsenic trioxide? How much arsenic and what volume of carbon monoxide is formed?

$$As_2O_3 + 3C = 3CO + As_2.$$

2. How much arsenic trioxide is formed by burning 3·567 gm. of arsenic in oxygen?

$$As_2 + 3O = As_2O_3.$$

3. The vapour of arsenic trioxide is 13·85 times as heavy as air. Find its double density referred to hydrogen.

4. How many grams do 2 litres of arsenic vapour (As_4) weigh?

5. Find the percentage composition of Proustite (Ag_3AsS_3).

6. 100 gm. of arsenic trioxide are heated with sulphur. What volume of sulphur dioxide at 39° C. and mass of orpiment are formed?

$$3As_2O_3 + 9S = 2As_2S_3 + 3SO_2.$$

7. 878 ccm. of arsine at 166° C. and 813 mm. occupy what volume at −41° C. and 696 mm.?

8. In a case of poisoning 11·73 grains of arsenic trisulphide were found. To how much arsenic trioxide does this correspond?

$$As_2S_3 + 9O = As_2O_3 + 3SO_2.$$

9. Find the percentage composition of Scheele's Green $CuHAsO_3$.

10. Calculate the percentage composition of potassium sulpharsenite K_3AsS_3.

11. Find the percentage composition of (α) realgar As_2S_2, (β) orpiment As_2S_3, (γ) arsenic pentasulphide As_2S_5.

12. A room 15 feet long and 10 feet high and wide is covered with paper containing 0·78 grain of Scheele's green ($CuHAsO_3$) per square foot. How much arsenic is there in the room?

13. 4 l. of hydrogen sulphide at 13° C. are passed into a solution of arsenic trioxide. How much arsenic trisulphide precipitates?

$$3H_2S + As_2O_3 = 3H_2O + As_2S_3.$$

14. What volume of hydrogen sulphide at 21° C. is required to precipitate the arsenic from a solution of 100 gm. of arsenic trioxide?

$$3H_2S + As_2O_3 = 3H_2O + As_2S_3.$$

15. 10 kilo. of arsenic trioxide are heated with hydrogen nitrate (Δ 1·35 cont. 56 % real acid). What volume of acid is required, how much hydrogen arsenate, and what volume of nitrogen trioxide at 13° C. is formed?

$$As_2O_3 + 2HNO_3 + 2H_2O = 2H_3AsO_4 + N_2O_3.$$

16. How much fluorspar and what volume of hydrogen sulphate (Δ 1·84) must be heated with 300 gm. of arsenic trioxide, and how much arsenic trifluoride is formed?

$$3CaF_2 + 3H_2SO_4 + As_2O_3 = 3CaSO_4 + 3H_2O + 2AsF_3.$$

17. How much arsenic must be acted on by what volume of chlorine at 13° C. and 720 mm. to make 100 ccm. of liquid arsenic trichloride (Δ 2·2)?

$$As + Cl_3 = AsCl_3.$$

18. What is the mass of 56 ccm. of the vapour of arsenic trichloride ($AsCl_3$) measured at 271·5° C.?

19. What volume of hydrogen arsenide at 15° C. can be obtained from 1 gm. of arsenic trioxide?

$$As_2O_3 + 6H_2SO_4 + 6Zn = 6ZnSO_4 + 3H_2O + 2H_3As.$$

20. What does a litre of hydrogen arsenide (H_3As) weigh?

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21. Find the percentage composition of Schweinfurt green ($Cu2C_2H_3O_2.3CuAs_2O_4$).

22. The specific heat of arsenic is 0·0814. And 96·15 pts. of arsenic combine with 3·85 pts. of hydrogen. Find the atomic weight of the element.

23. How much zinc is dissolved in forming 1·37 l. of hydrogen arsenide at 40° C. and 600 mm.?

$$6Zn + As_2O_3 + 6H_2SO_4 = 6ZnSO_4 + 3H_2O + 2H_3As.$$

24. What volume is occupied by 4 gm. of cacodyl $As_2(CH_3)_4$ vapour at 210° C. and 780 mm.?

CHAPTER XX.

ANTIMONY, Sb = 120. BISMUTH, Bi = 208.

1. How much antimony is there in 1020 kilo. of the trisulphide (Sb_2S_3)?

2. Find the mass of a sheet of antimony (Δ 6·7) 20 cm. long, 10 cm. wide, and 1 mm. thick.

3. What volume is occupied by 100 gm. of (α) arsenic Δ 5·8, (β) antimony Δ 6·8, (γ) bismuth Δ 9·9?

4. Type metal is an alloy of 80 pts. of lead (Δ 11·3) and 20 pts. of antimony (Δ 6·7). If no permanent change of volume takes place during the fusion, what is the density of the alloy?

5. According to Cooke, 100 gm. of antimony tribromide ($SbBr_3$) contain 33·3335 of antimony and 66·6665 gm. of bromine. What is the atomic weight of antimony?

6. 100 gm. of antimony gave 124·8 gm. of antimony tetroxide. If O = 100 what is the atomic weight of antimony?

$$2Sb + 4O = Sb_2O_4.$$

7. What volume of chlorine at 13° C. is required to convert 100 gm. of antimony into the trichloride?

$$2Sb + 6Cl = 2SbCl_3.$$

8. A piece of antimony was converted into the tribromide by absorbing 187 ccm. of bromine vapour. What was the mass of the antimony?

$$Sb + 3Br = SbBr_3.$$

9. What volume of chlorine at 17° C. is required to convert 100 gm. of antimony into the pentachloride?

$$2Sb + 5Cl_2 = 2SbCl_5.$$

10. What volume of hydrogen sulphide under a pressure of 567 mm. is evolved on dissolving 33·6 gm. of antimony trisulphide in hydrogen chloride?

$$Sb_2S_3 + 6HCl = 2SbCl_3 + 3H_2S.$$

11. 10 l. of hydrogen sulphide at 15° C. are passed into a solution of antimony trichloride. How much antimony trisulphide precipitates?

$$3H_2S + 2SbCl_3 = 6HCl + 2Sb_2S_3.$$

12. What would a litre of pure hydrogen antimonide (H_3Sb) at 13° C. weigh?

13. 4 l. of mixture of hydrogen and hydrogen antimonide at 26° C. and 800 mm. are passed through a red-hot tube which is found to increase in mass by 15 gm. Find the percentage composition of the mixture by volume.

$$2SbH_3 = 2Sb + 3H_2.$$

14. Bismuth melts at 264° C. What temperature is this on the Fahrenheit and on the Réaumur scale?

15. Find the percentage composition of the four oxides of bismuth (α) Bi_2O_2, (β) Bi_2O_3, (γ) Bi_2O_4, (δ) Bi_2O_5.

16. What is the percentage composition of bismuth nitrate ($Bi3NO_35H_2O$)?

17. Schneider found that 54·969 gm. of bismuth formed 61·311 gm. of the trioxide. What is the atomic weight of bismuth?

$$2Bi + 3O = Bi_2O_3.$$

18. What volume of oxygen at 30° C. is given off on heating 100 gm. of bismuth pentoxide?

$$Bi_2O_5 = Bi_2O_4 + O.$$

19. What volume of chlorine at 12° C. is required to convert 9·28 gm. of bismuth trioxide into the pentoxide?

$$Bi_2O_3 + 2H_2O + 4Cl = 4HCl + Bi_2O_5.$$

20. What volume of chlorine at 9° C. is required to convert 70 gm. of bismuth into the trichloride?

$$Bi + Cl_3 = BiCl_3.$$

21. Arcet's alloy consists of 5 pts. of lead (Δ 11·45), 3 pts. of tin (Δ 7·3), and 8 pts. of bismuth (Δ 9·9). If no permanent change of volume take place, find the density of the alloy.

22. Wood's alloy consists of 2 pts. of lead (Δ 11·45), 4 pts. of tin (Δ 7·3), 2 pts. of cadmium (Δ 8·7), and 8 pts. of bismuth (Δ 9·9). If no permanent change of volume takes place, find the density of the alloy.

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23. Find the percentage composition of $2C_4H_4K(SbO)O_6.H_2O$, tartar emetic.

24. A cubic decimetre of antimony sulphide (Δ 4·62) is dissolved in hydrogen chloride. What volume of hydrogen sulphide at 30° C. and 800 mm. is given off?

$$Sb_2S_3 + 6HCl = 2SbCl_3 + 3H_2S.$$

25. What volume is occupied by 10 gm. of trimethylstibine $Sb(CH_3)_3$ at 300° C.?

26. What is the mass of a spherical pellet of bismuth (Δ 9·9) 2 mm. in diameter?

CHAPTER XXI.

THE PHYSICAL PROPERTIES OF METALS. I.

MASS, VOLUME, AND DENSITY.

1. Find the volume of 100 gm. of (α) platinum Δ 21·5, (β) gold Δ 19·3, (γ) lead Δ 11·4, (δ) lithium Δ 0·59.

2. A kilo. of copper (Δ 8·9), a kilo. of silver (Δ 10·5), and a kilo. of mercury (Δ 13·5) are placed in a vessel full of water. What volume runs over?

3. Find the mass of a potassium (Δ ·86) wire 2 mm. in diameter and 1 decimetre long.

4. How many grams does a stick of sodium (Δ ·97) 1 cm. square and 1 dm. long weigh?

5. How many spherical pellets of potassium (Δ ·86) half an inch in diameter can be made from an ounce of the metal?

6. What is the radius of a strontium (Δ 2·54) wire 10 cm. long which weighs 2·6 gm.?

7. What is the mass of a sheet of aluminium (Δ 2·67) 1 mm. thick, 1 dm. across, and 1 m. long?

8. How many yards of wire $\frac{1}{16}$ inch in diameter can be made from an ounce of magnesium (Δ 1·74)?

9. A pellet of manganese weighed in ether (Δ ·7024) 14·6212 gm. and in chloroform (Δ 1·5252) 12·9756 gm. Find the density of the metal.

10. An iron (Δ 7·8) armour-plate is 12 ft. long, 4 ft. wide, and 6 inches thick; find its mass in tons.

11. What is the mass in kilograms of an iron (Δ 7·7) beam 12 ft. long, 6 inches broad, and 9 inches deep?

12. How many kilo. does an iron (Δ 7·8) telegraph wire 16 kilom. long and 2 mm. in diameter weigh?

13. What is the mass of a cylindrical cast iron (Δ 7·25) cannon bolt 10 cm. in diameter and 15 ccm. long?

14. Find the mass in tons of a forged steel (Δ 7·8) cylinder 13 m. long and a metre in diameter.

15. An empty spherical Mallet shell (Δ 7·25) is a yard in diameter and two inches thick. Find its mass in kilograms.

16. How many grams does a cubic foot of pure iron (Δ 7·88) weigh more than a cubic foot of steel (Δ 7·75)?

17. A decimetre cube of cast iron (Δ 7·25) floats upon mercury (Δ 13·596) with one face horizontal. How far is the cube immersed in the mercury?

18. A meteorite (Δ 7·5) contains 3 times its volume of hydrogen. How many times is the meteorite heavier than the hydrogen?

19. What is the diameter in inches of a cast iron (Δ 7·25) 32 lb. cannon-ball?

20. A sheet of tin-foil (Δ 7·3) is a yard long, a foot wide, and ·01 inch thick. Find its mass in grams.

21. A sheet of iron (Δ 7·8) 1 m. square and 1 mm. thick is dipped into melted tin. If its original mass be increased by $\frac{1}{10}$, what is the thickness of the layer of tin (Δ 7·3)?

22. A circular sheet of cardboard 1 m. across is covered on one side with tin-foil (Δ 7·3) 0·02 mm. thick. By how many grams does the cardboard increase in mass?

23. A roll of sheet-lead (Δ 11·4) is 20 ft. long, 6 ft. wide, and $\frac{1}{8}$ inch thick. How many pounds does it weigh?

24. Find the number of pounds of lead, 1 sq. ft. of which weighs 5 lb., on a roof 36 ft. 9 inches long, and 16 ft. 8 inches wide.

25. How many shot 1 mm. in diameter can be made from 1000 gm. of lead (Δ 11·46)?

26. 1000 ccm. of mercury at 0° C. (Δ 13·596) are cooled to − 40° C. What is the volume of the solid mercury (Δ 14·39)?

27. What is the capacity of an iron bottle, which contains 70 lb. of mercury (Δ 13·56)?

28. What is the radius of a cylindrical tube 10 cm. long, which is found to hold 4·26 gm. of mercury (Δ 13·56)?

29. A glass tube 20 cm. long contains 121 gm. of mercury (Δ 13·51). Find its radius.

30. A spherical glass bulb is found to hold 509·52 gm. of mercury (Δ 13·51). What is the internal radius of it?

31. How many pounds does a sheet of silver (Δ 10·5) a yard long, a foot wide, and an inch thick weigh?

32. Silver (Δ 10·54) has been deposited on glass so thin that a square metre weighed 2·2 grams. How thick was the coating?

33. A nugget of gold (Δ 19·3) weighed 1743 ounces troy; what was its mass in kilograms and its volume in cubic centimetres?

34. A sovereign ought to contain 113·001 grains of gold (Δ 19·3). If the gold in the £124,000,000 in circulation were made into a cube, how many feet long would the edge be?

35. Find the radius of a gold (Δ 19·3) ball equal in mass to a silver (Δ 10·5) ball the radius of which is 15 cm.

36. The ball at the top of St. Paul's is 6 ft. in diameter, and covered with gold (Δ 19·3) $\frac{1}{2000}$ inch thick. Find the mass of the gold in kilograms.

37. A platinum $\frac{1}{2}$ gm. weight (Δ 21·5) is 1 cm. square. How thick is it?

38. The English standard platinum kilogram (Δ 21·1379) is a cylinder 4 cm. high. What is its radius?

39. How much does a 100 gm. platinum weight (Δ 21·2) lose in air at 15° C.?

40. How many grains of normal air are displaced by (α) the standard Platinum Pound (Δ 21·1572), (β) the Quartz standard Pound (Δ 2·605)?

MALLEABILITY AND DUCTILITY.

41. What length of wire 2 mm. in diameter can be drawn from a cubic decimetre of metal?

42. How many grams does a sheet of iron (Δ 7·8) 1 m. square and $\frac{1}{100}$ mm. thick weigh?

43. A gram of silver (Δ 10·5) can be drawn into a wire 2600 m. long. What is the diameter of the wire?

44. A grain of silver (Δ 10·5) can be drawn into a wire 400 feet long. What is the radius of the wire in mm.?

45. Gold leaf can be made $\frac{1}{200000}$ inch thick. What would be the length of the side of a square of such leaf containing one grain of gold (Δ 19·3)?

46. A sheet of gold leaf (Δ 19·3) 0·0001 mm. thick weighs one gram. What is its area in scm.?

47. A wire of gold (Δ 19·3) 3 kilom. in length weighs a gram. Find the radius in mm.

48. Faraday calculated that the gold (Δ 19·3) in four sovereigns (452·004 grains) could be made into a wire long enough to go round the world ($r = 6{\cdot}37 \times 10^6$ m.). Find the radius of such a wire in cm.

49. If a sheet of platinum foil (Δ 21·5) is 211 mm. long and 56 mm. wide and weighs 10·2 gm., what is the thickness?

50. A platinum wire (Δ 21·5) is 102 mm. long and weighs 0·18 gm. What is the radius?

51. Platinum wire (Δ 21·5) can be made $\frac{1}{10000}$ mm. in diameter. How many grams would such a wire 21,600 geographical miles long weigh?

52. How many metres of wire $\frac{1}{8}$ mm. in diameter can be made from one ounce troy of platinum (Δ 21·5)?

TENACITY.

53. If a lead wire $\frac{1}{\pi}$ inch in diameter will just carry 20 lb., how many kilo. will a wire 1 mm. in radius carry?

54. A lead wire 1 mm. square will carry 2 kilo. What is the length of an iron weight 20 cm. square (Δ 7·25) which a leaden rod 1 cm. square will just carry?

55. The tenacity of zinc is 7000 lb. per square inch. How many kilo. will a zinc wire 2 mm. in radius carry?

56. The best Low Moor iron will carry 64,200 lb. per square inch. How many kilo. will a wire 2 mm. in diameter carry?

57. A steel wire 1 mm. square will resist a pull of 70 kilo. How many tons will a rod 1 inch square carry?

58. An iron wire 2 mm. in diameter will carry 250 kilo., a similar nickel wire 375 kilo., and a similar cobalt wire 479 kilo. Find the diameter of a wire of each metal which will just carry 1000 kilo.

59. A rod of best charcoal iron will carry 114,000 lb. per square inch. Find the radius in cm. of an iron (Δ 7·8) sphere which a rod of such iron 1 cm. square will carry.

60. Copper wire will carry 40 kilo. per smm. A pull of how many lbs. is required to break a bell-wire 0·08 inch in diameter?

61. Mr. Cowles' silico-aluminium bronze will carry 200,000 lb. per square inch. How many kilo. can be carried by a wire 2 mm. in diameter?

CHAPTER XXII.

THE PHYSICAL PROPERTIES OF METALS. II.

ALLOYS.

Unless otherwise stated it is assumed that the volume of an alloy is equal to the volume of its constituents.

1. How many kilo. of copper (Δ 9) and of tin (Δ 7·32) are contained in 112 kilo. of an alloy (Δ 8·784)?

2. Find the density of gun-metal which contains 10 pts. tin (Δ 7·3) and 90 pts. copper (Δ 8·9).

3. What is the density of Britannia metal which contains 9 pts. of tin (Δ 7·8) and 1 pt. of antimony (Δ 6·8)?

4. An alloy of equal masses of platinum (Δ 21·5) and copper (Δ 9) is found to have the same colour and density (Δ 19·5) as gold. In alloying 100 volumes of the two metals what contraction takes place?

5. When weighing with brass (Δ 8·4) weights in normal air, how much is apparently lost by the weights per gram?

6. Find the density of aluminium bronze, which contains 10% of aluminium (Δ 2·6) and 90% of copper (Δ 8·9).

7. Find the density of an alloy of equal parts of magnesium (Δ 1·7), zinc (Δ 7), and cadmium (Δ 8·5).

8. Find the density of an alloy of equal parts of tin (Δ 7·3) and lead (Δ 11·45).

9. What is the density of an alloy of 100 gm. of lead (Δ 11·45) with 300 gm. of tin (Δ 7·3)?

10. One volume of tin (Δ 7·3) combines without change of volume with two volumes of mercury (Δ 13·56). What is the density of the amalgam?

11. A shilling (Δ 10·2) weighs 87·27 grains. What is its volume in ccm.?

12. An alloy of equal parts of silver (Δ 10·5) and bismuth (Δ 9·8) is found to have the density 10·709. If no change of volume took place what would the density of the alloy be?

13. Mint-silver (Δ 10·2) consists of 7·5 % of copper (Δ 8·9) and 92·5 % of silver (Δ 10·5). What would be the density of the alloy if no change of volume took place, and what do 100 volumes of the two metals occupy after the fusion?

14. 900 gm. of gold (Δ 19·3) are fused with 100 gm. of silver (Δ 10·5). What is the density of the alloy?

FUSIBILITY.

15. Zinc melts at 773° F., and boils at 1904° F. What are these temperatures on the Centigrade scale?

16. Cadmium becomes brittle at 180° F., melts at 242° F., and boils at 1580° F. What are these temperatures on the Centigrade scale?

17. 100 gm. of copper (sp. ht. ·095) were heated to the melting point and thrown into a kilo. of water at 0° C. The temperature of the mixture was found to be 10·35° C. What is the melting point of copper?

18. 100 gm. of platinum (sp. ht. 0·03243) were heated in a furnace and plunged into a vessel of water, weighing when reduced to water 976 gm. The temperature of the water rose from 10° C. to 15° C. What was the temperature of the furnace?

EXPANSIBILITY.

The co-efficient of cubical expansion of mercury for 1° *C. is* $\frac{1}{5550}$ *or* ·000181.

19. Edinburgh is 400 miles from London. By how many yards do the lines (co-eff. exp. ·00001166) expand when heated from 0° C. to 30° C. ?

20. The barometer, read on a brass (co-eff. exp. 0·00002) scale at 10° C., was 786·4 mm. What is the reading reduced to 0° C. ?

21. The barometer, read on a glass scale (co-eff. exp. ·000009) at 20° C., was 770 mm. What is the reading reduced to 0° C. ?

22. A brass (co-eff. lin. exp. ·000019) cylinder measures 24·4 cm. in height and breadth at 17·5° C. What is the volume of it ? And what would the volume become at 0° C. ?

23. 493 ccm. of mercury are measured off at 15° C. What volume do they occupy at 25° C. ?

24. 100 vol. of mercury at 0° C. (Δ 13·596) become 102 vol. at 110° C. Find the density at the latter temperature.

25. The density of mercury at 0° C. is 13·596. What is the density at 15° C. ?

26. What column of mercury at 15° C. produces a pressure equal to that of a column of water of 273 mm. ?

27. What is the volume at 0° C. of a glass bulb (co-eff. cub. exp. ·00003) which at 25° C. contains 53 gm. of mercury ?

28. A glass bulb weighing 430 grains, when filled with mercury at 0° C., weighs 1510 grains. It is placed in hot oil, and after cooling weighs 1490 grains. If the co-efficient of apparent expansion of mercury in glass be $\frac{1}{6480}$, at what temperature Centigrade was the oil ?

29. By how many cubic centimetres would 69 units of heat cause a litre of mercury (sp. ht. ·0333) at 0° C. to expand ?

30. A thermometer contains 11 gm. of mercury (sp. ht. ·0333). What quantity of heat is required to raise the mercury from 0° C. to 100° C., and what increase in volume will show 1° C. ?

31. A piece of thermometer tube 2 dm. long was found to hold 0·2 gm. of mercury. What must the internal volume of the bulb be that 0° C. to 100° C. on the stem may measure 2 dm. ?

32. A glass bulb was found to hold 600 gm. of mercury at 0° C., and 591 gm. after heating to 100° C. What is the co-efficient of cubical expansion of the glass ?

CHAPTER XXIII.

POTASSIUM, K = 39.

1. How much potassium carbonate and charcoal must be heated together to form a kilogram of potassium?

$$K_2CO_3 + 2C = 3CO + K_2.$$

2. What volume of carbon monoxide at 455° C. is given off during the separation of 100 gm. of potassium?

$$K_2CO_3 + 2C = 3CO + K_2.$$

3. How much (α) potassium carbonate, (β) calcium hydrate is required to make a kilogram of potassium hydrate?

$$K_2CO_3 + H_2CaO_2 = CaCO_3 + 2HKO.$$

4. What volume of oxygen at 15° C. is required to convert 10 gm. of potassium into the tetroxide?

$$K_2 + 2O_2 = K_2O_4.$$

5. 5 gm. of potassium tetroxide are boiled with water. What volume of oxygen at 100° C. is evolved?

$$K_2O_4 + H_2O = 2HKO + 3O.$$

6. How many grams does a stick of potassium hydrate (Δ 2·2) 1 cm. across and 10 cm. long weigh?

7. A pellet of potassium (Δ 0·86) 1 cm. in diameter is thrown in small fragments into water. What volume of hydrogen at 15° C. is given off?

$$K + H_2O = HKO + H.$$

8. Potassium (Δ 0·86) absorbs 126 times its volume of hydrogen. Find a formula for the body formed.

9. What is the percentage composition of potassium silicofluoride K_2SiF_6?

10. Calculate the percentage composition of feldspar $K_2Al_2Si_6O_{16}$.

11. How much potassium chloride must be mixed with a kilo. of Chili nitre, and how much potassium nitrate is formed?

$$NaNO_3 + KCl = NaCl + KNO_3.$$

12. 100 gm. of potassium nitrate are heated to redness. What volume of oxygen at 39° C. is evolved?

$$KNO_3 = KNO_2 + O.$$

13. 20 gm. of potassium nitrate are heated with potassium dichromate. What volumes of oxygen and of nitrogen tetroxide at 20° C. are evolved?

$$2KNO_3 + K_2Cr_2O_7 = 2K_2CrO_4 + 2NO_2 + O.$$

14. If a gram of powder form 280 ccm. of gas at 0° C., what volume would be occupied at 2200° C.?

15. What volume of gas is formed by 100 gm. of powder (α) at 0° C., (β) at 1000° C., if the decomposition be

$$2KNO_3 + S + 3C = K_2S + N_2 + 3CO_2.$$

16. R. L. G. powder produces a pressure of 4690 atmospheres. What is this pressure in tons per square inch?

17. 10 gm. of potassium and hydrogen carbonate are heated. What volume of carbon dioxide at 30° C. is given off?

$$2HKCO_3 = K_2CO_3 + H_2O + CO_2.$$

18. 4 gm. of potassium and hydrogen carbonate are dissolved in hydrogen chloride. What volume of carbon dioxide at 52° C. is given off?

$$HKCO_3 + HCl = KCl + H_2O + CO_2.$$

19. A gasogen holding 4 litres is charged with 4 ounces of potassium and hydrogen carbonate and hydrogen tartrate, but only a very small quantity of water is added. What is the pressure of the gas at 10° C.?

$$2HKCO_3 + H_2\overline{T} = K_2\overline{T} + 2H_2O + 2CO_2.$$

20. A substance contains potassium 28·25, chlorine 25·64, and oxygen 46·11 per cent. Find its formula.

21. What volume of oxygen at 94·5° C. and 960 mm. is evolved on heating 260 gm. of potassium chlorate?

$$KClO_3 = KCl + O_2.$$

22. What volume of hydrogen fluoride at 90° C. is evolved on heating 100 gm. of potassium and hydrogen fluoride?

$$HKF_2 = KF + HF.$$

23. What volume of hydrogen sulphide at 15° C. and 780 mm. is required to reduce 100 gm. of potassium bromate?

$$KBrO_3 + 3H_2S = KBr + 3H_2O + 3S.$$

24. According to Stas 100 gm. of potassium chloride form 135·6423 gm. of potassium nitrate. What is the atomic weight of potassium?

$$KCl + HNO_3 = HCl + KNO_3.$$

CHAPTER XXIV.

SODIUM, Na = 23.

1. How much sodium can be obtained from 20 kilo. of sodium carbonate, and what volume of carbon monoxide is formed in the process?

$$Na_2CO_3 + 2C = 3CO + Na_2.$$

2. What volume of oxygen at 200° C. is required to convert 100 gm. of sodium into the dioxide?

$$Na_2 + O_2 = Na_2O_2.$$

3. The specific heat of sodium is 0·2934, and 39·32 gm. of sodium unite with 135·765 gm. of bromine. What is the atomic weight of sodium?

$$Na + Br = NaBr.$$

4. A gram of sodium amalgam, when thrown into water, evolved 200 ccm. of hydrogen at 13° C. What was the percentage of sodium in the amalgam?

$$Na_2 + 2H_2O = 2NaHO + H_2.$$

5. What volume of hydrogen at 26° C. and 740 mm. is evolved by the action of 0·2 gm. of sodium upon water, and what will the gas measure over water?

$$Na_2 + 2H_2O = 2HNaO + H_2.$$

6. How much sodium carbonate and slaked lime must be used to make a kilogram of sodium hydrate?

$$Na_2CO_3 + H_2CaO_2 = CaCO_3 + 2HNaO.$$

7. Find the percentage composition of (α) dry Na_2CO_3, (β) crystallized $Na_2CO_3 10H_2O$ sodium carbonate.

8. What is the percentage of sodium sulphate and of water in Glauber's salts $Na_2SO_4.10H_2O$?

9. How many pounds of common salt are required to make 500 lbs. of salt-cake?

$$2NaCl + H_2SO_4 = 2HCl + Na_2SO_4.$$

10. How much sodium carbonate can be made from 500 kilo. of common salt?

$$2NaCl + H_2SO_4 = 2HCl + Na_2SO_4.$$
$$Na_2SO_4 + CaCO_3 + 4C = 4CO + CaS + Na_2CO_3.$$

11. If 100 tonnes of common salt are decomposed by hydrogen sulphate, how much salt-cake and what volume of aqueous hydrogen chloride (Δ 1·2 cont. 41% real acid) are formed?

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

12. If 100 gm. of sodium sulphate are heated with charcoal, how much sodium sulphide, and what volume of carbon monoxide at 15° C. is formed?

$$Na_2SO_4 + 4C = Na_2S + 4CO.$$

13. 1000 kilo. of common salt will form how much salt-cake and what volume of hydrogen chloride gas?

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

14. How many kilo. of soda crystals containing 3 per cent. of impurity, and how many kilo. of hydrochloric acid (Δ 1·21) containing 480 times its volume of the gas, can be formed from the materials in the last question?

$$10H_2O + Na_2SO_4 + 4C + CaCO_3 = CaS + 4CO + Na_2CO_3.10H_2O.$$

15. What volume of carbon dioxide at 77° C. is absorbed in converting 10 kilo. of crystallized sodium carbonate into bicarbonate?

$$Na_2CO_3 10H_2O + CO_2 = 9H_2O + 2HNaCO_3.$$

16. What volume of carbon dioxide can be obtained from 3·72 gm. of "bicarbonate of soda" (α) by heating, (β) by the action of an acid?

$$2HNaCO_3 = H_2O + Na_2CO_3 + CO_2.$$
$$HNaCO_3 + HCl = NaCl + H_2O + CO_2.$$

17. A sample of soda-ash is found to contain 56 per cent. of sodium oxide (Na_2O). How much sodium carbonate (Na_2CO_3) per cent. is there in the ash?

18. In trade analyses the atomic weight of sodium is often taken as 24 instead of 23. Find the error per cent. introduced if the result be calculated (α) as sodium, (β) as sodium carbonate.

19. Find the formula of albite, which contains silica 68·44, alumina 19·45, sodium oxide 11·67, and potassium oxide 0·43 per cent.

20. Sea-water (Δ 1·027) contains 2·64 per cent. of sodium chloride (NaCl). How many pounds of sodium are there in a cubic yard of sea-water?

21. 10 gm. of sodium and hydrogen sulphite are heated. What volume of sulphur dioxide is given off?

$$2NaHSO_3 = Na_2SO_3 + H_2O + SO_2.$$

22. If 10 gm. of sodium sulphite are dissolved in acid, what volume of sulphur dioxide at 12° C. is given off?

$$Na_2SO_3 + 2HCl = H_2O + 2NaCl + SO_2.$$

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23. A cubical crystal of rock-salt (Δ 2·16) weighs 43·2 gm. Find the length of its edge.

24. Sodium hydride (Δ 0·959) contains 46 pts. of sodium (Δ 0·97) and 1 pt. of hydrogen. Find the density of the solid "hydrogenium."

25. A mixture of potassium and sodium chlorides weighed 4·2 gm. When converted into sulphates the mixed salts weighed 5 gm. How much (α) potassium, (β) sodium was present?

$$2[KNa]Cl + H_2SO_4 = 2HCl + [K_2Na_2]SO_4.$$

26. 1·221 gm. of a mixture of potassium and sodium carbonates gave 1·231 gm. of the mixed chlorides, from which 2·87 gm. of silver chloride were formed. Find the percentage composition of the mixture.

$$[Na_2K_2]CO_3 + 2HCl = H_2O + CO_2 + 2[NaK]Cl.$$
$$[NaK]Cl + AgNO_3 = [KNa]NO_3 + AgCl.$$

CHAPTER XXV.

AMMONIUM, $NH_4 = 18$.

1. Find the formula of a substance containing nitrogen 26·17, hydrogen 7·48, and chlorine 66·35 per cent.

2. 20 gm. of ammonium sulphate are heated with lime. What volume of ammonia is given off?

$$(NH_4)_2SO_4 + CaO = H_2O + CaSO_4 + 2NH_3.$$

3. A kilo. of ammonium chloride is heated with lime. What volume of ammonia at 12° C. is evolved?

$$2NH_4Cl + CaO = CaCl_2 + H_2O + 2NH_3.$$

4. 100 gm. of ammonium nitrite are heated. What volume of nitrogen at 13° C. is evolved?

$$NH_4NO_2 = 2H_2O + N_2.$$

5. A kilo. of ammonium nitrate is heated. What volume of nitrous oxide at 15° C. is evolved?

$$NH_4NO_3 = 2H_2O + N_2O.$$

6. Water at 0° C. absorbs 1000 times its volume of ammonia. How many grams of solution of ammonia can be made from a litre of water?

7. How many pints of solution of ammonia (Δ ·88) weigh 4 lbs.?

8. How much ammonium chloride is there in a litre of a solution, 20 cm. of which, after precipitation with platinum tetrachloride and ignition, gave 0·976 gm. of platinum?

$$2NH_4Cl + PtCl_4 = (NH_4)_2PtCl_6.$$
$$(NH_4)_2PtCl_6 = 2NH_3 + 2HCl + 2Cl_2 + Pt.$$

9. Find the percentage composition of (α) ammonium and hydrogen carbonate $(NH_4)_4H_2(CO_3)_3$, (β) ammonium carbamate $(NH_2)_2CO_2$.

10. 40 gm. of microcosmic salt are heated. How much sodium metaphosphate, what volumes of ammonia at 15° C., and of steam at 300° C. are formed?

$$Na(NH_4)HPO_4.4H_2O = NaPO_3 + NH_3 + 5H_2O.$$

Hydroxylamine, $NH_3O = 33$.

11. What volume of nitric oxide at 10° C. must be caused to combine with what volume of hydrogen at 20° C. to form 100 gm. of hydroxylamine?

$$NO + 3H = NOH_3.$$

12. 2 gm. of hydroxylamine are heated with potassium hydrate. What volumes of nitrogen and of ammonia at 21° C. are formed?

$$3NOH_3 = N_2 + NH_3 + 3H_2O.$$

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13. What volume is occupied by the vapour of one gram of ammonium chloride (NH_4Cl) at 350° C. and 700 mm.?

14. Water at 15° C. absorbs 740 times its volume of ammonia at 15° C. How much water is there in a litre of such a solution (Δ 0·855), and how much ammonium chloride is required to make it?

$$2NH_4Cl + CaO = CaCl_2 + H_2O + 2NH_3.$$

15. 10 gm. of silver chloride are saturated with ammonia and heated. (α) What volume of ammonia at 50° C. is evolved? (β) How much sodammonium can be formed from the liquefied ammonia?

$$AgCl2NH_3 = AgCl + 2NH_3.$$
$$2NH_3 + Na_2 = N_2H_6Na_2.$$

CHAPTER XXVI.

CALCIUM, Ca = 40.

1. How much calcium is contained in 100 gm. of (α) marble $CaCO_3$, (β) gypsum $CaSO_4.2H_2O$, (γ) fluor-spar CaF_2, (δ) superphosphate of lime $CaH_4 2PO_4$?

2. How many tons of chalk must be "burnt" to form 100 tons of quick-lime?

$$CaCO_3 = CO_2 + CaO.$$

3. How much calcium hydrate can be obtained by heating 2·726 kilo. of calc-spar to redness and throwing water on the residue?

$$CaCO_3 = CaO + CO_2.$$
$$CaO + H_2O = H_2CaO_2.$$

4. Calcium hydrate is soluble in 720 times its mass of cold, and in 1300 times its mass of boiling water. How much of the hydrate precipitates on boiling a litre of the solution?

5. A substance contains calcium 39·9, carbon 12·1, and oxygen 48 per cent. Find the formula of it.

6. A salt contains calcium 27·4, carbon 16·44, oxygen 43·84, and water 12·33 per cent. Find the formula.

7. A cubic metre of marble ($CaCO_3$, Δ 2·7) contains how many times its volume of gaseous carbon dioxide condensed in it?

8. 10 gm. of marble are dissolved in hydrogen chloride. What volume of carbon dioxide at 30° C. is given off?

$$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2.$$

9. 1000 kilo. of limestone are "burnt." What volume of carbon dioxide at 300° C. is given off?

$$CaCO_3 = CaO + CO_2.$$

10. A litre of water saturated with carbon dioxide dissolves 0·88 gm. of calcium carbonate. How many gallons of water are required to dissolve a ton of chalk?

11. How many grams of calcium chloride ($CaCl_2$) must be dissolved in a litre of water to be equivalent to a *hard* water containing *x grains* of calcium carbonate per gallon?

12. What volume of a solution of calcium sulphate (containing 2·33 gm. of the salt per litre) must be made up to 200 ccm. to give a hardness of 16° Clark per gallon?

13. 1000 gm. of sea-water contain 1·33 gm. of calcium sulphate and 0·047 gm. of calcium carbonate. How much sea-water would give 3·24 gm. of calcium oxalate?

$$CaSO_4 + (NH_4)_2C_2O_4 = (NH_4)_2SO_4 + CaC_2O_4.$$
$$CaCO_3 + (NH_4)_2C_2O_4 = (NH_4)_2CO_3 + CaC_2O_4.$$

14. How much calcium sulphate can be formed from 11·1 gm. of calcium chloride?

$$CaCl_2 + H_2SO_4 = 2HCl + CaSO_4.$$

15. How many ccm. of water are required to make 100 gm. of plaster of Paris set?

$$CaSO_4 + 2H_2O = CaSO_4 2H_2O.$$

16. How many grams does a pound of selenite lose when heated to 200° C.?

$$CaSO_4 2H_2O = CaSO_4 + 2H_2O.$$

17. A cistern 10 ft. square and 6 ft. deep contains water saturated with calcium sulphate, which is soluble in 400 times its weight of water. How many kilograms of the salt are there in the cistern?

18. 700 ccm. of water containing 1 gm. of calcium hydrate in solution are mixed with 700 ccm. containing 1·26 l. of carbon dioxide in solution. What mass of which substance remains in solution?

$$CaH_2O_2 + CO_2 = H_2O + CaCO_3.$$

19. A litre of air at 12° C., when shaken up with lime-water, gave 0·0017 gm. of calcium carbonate. What is the percentage by volume of carbon dioxide in air?

$$CaH_2O_2 + CO_2 = CaCO_3 + H_2O.$$

20. 100 parts of water at 180° C. dissolve 325 parts of dry calcium chloride. How many ccm. of water must be added that a saturated solution of a kilogram of the dry salt may crystallize ($CaCl_2 6H_2O$)?

21. 100 pts. of calcium chloride combine with 119 pts. of ammonia. Find a formula for the compound.

22. 100 gm. of bleaching powder are heated with water and cobalt oxide. What volume of oxygen at 21° C. is evolved?

$$2CaOCl_2 = 2CaCl_2 + O_2.$$

CHAPTER XXVII.

STRONTIUM, Sr = 87·6. BARIUM, Ba = 137.

1. Find the percentage composition of (α) strontianite $SrCO_3$, (β) celestine $SrSO_4$, (γ) witherite $BaCO_3$, (δ) heavy spar $BaSO_4$.

2. 2 gm. of strontium are obtained by passing a current of electricity through the fused chloride. What volume of chlorine at 15° C. is set free?

$$SrCl_2 = Sr + Cl_2.$$

3. How much strontia is obtained on heating 1000 gm. of strontium nitrate?

$$Sr2NO_3 = 2NO_2 + O + SrO.$$

4. Crystallized strontium hydrate is soluble in 50 times its mass of water. How much hydrogen sulphate will 100 gm. of the solution precipitate?

$$H_2SrO_28H_2O + H_2SO_4 = 10H_2O + SrSO_4.$$

5. According to Marignac 10 gm. of crystallized strontium chloride give 6·8855 gm. of strontium sulphate. What is the atomic weight of strontium?

$$SrCl_26H_2O + H_2SO_4 = 6H_2O + 2HCl + SrSO_4.$$

6. What is the probable specific heat of barium?

7. How much baryta can be made from 10 kilo. of barium nitrate?

$$Ba2NO_3 = BaO + 2NO_2 + O.$$

8. Crystallized barium hydrate ($H_2BaO_28H_2O$) is soluble in 20 times its mass of cold water. How much barium hydrate is there in 100 gm. of the saturated solution?

9. A litre of carbon dioxide at 15° C. is drawn through baryta water. How much barium carbonate precipitates?

$$H_2BaO_2 + CO_2 = H_2O + BaCO_3.$$

10. 1000 l. of air (containing 0·037 per cent. by volume of carbon dioxide) are drawn through baryta-water. How much barium carbonate precipitates?

$$CO_2 + H_2BaO_2 = H_2O + BaCO_3.$$

11. 59 l. of air are drawn over heated baryta. How much barium dioxide is formed?

$$BaO + O = BaO_2.$$

12. What volume of oxygen at 21° C. is absorbed by 100 gm. of heated baryta?

$$BaO + O = BaO_2.$$

13. What volume of carbon dioxide at 13° C. is required to precipitate the barium from 100 gm. of hydrated barium dioxide?

$$BaO_2 6H_2O + CO_2 = BaCO_3 + H_2O_2 + 5H_2O.$$

14. What volume of oxygen at 15° C. and 700 mm. is given off on heating 14 gm. of barium dioxide?

$$BaO_2 = BaO + O.$$

15. What volume of sulphur dioxide at 39° C. must be passed over 100 gm. of heated barium dioxide to convert them into sulphate?

$$SO_2 + BaO_2 = BaSO_4.$$

16. One gram of calcium sulphate will form how much barium sulphate?

$$CaSO_4 + BaCl_2 = CaCl_2 + BaSO_4.$$

17. 20 gm. of witherite are dissolved in hydrogen chloride. How much crystallized barium chloride and what volume of carbon dioxide are formed?

$$BaCO_3 + 2HCl + H_2O = CO_2 + BaCl_2 2H_2O.$$

18. 0·591 gm. of witherite gave 0·699 gm. of barium sulphate. Find the percentage of barium in the witherite.

$$BaCO_3 + H_2SO_4 = H_2O + CO_2 + BaSO_4.$$

19. How much hydrogen sulphate will 1 ccm. of a solution of barium chloride, containing 100 gm. of the crystallized salt per litre, precipitate?

$$BaCl_2 2H_2O + H_2SO_4 = 2H_2O + 2HCl + BaSO_4.$$

20. A mixture of barium and calcium chlorides gave 10 gm. of the mixed carbonates. And the precipitate when redissolved gave 12 gm. of the mixed sulphates. How much barium and how much calcium was present?

$$[BaCa]Cl_2 + 2NH_4CO_3 = 2NH_4Cl + [BaCa]CO_3.$$
$$[BaCa]Cl_2 + (NH_4)_2SO_4 = 2NH_4Cl + [BaCa]SO_4.$$

CHAPTER XXVIII.

ALUMINIUM, Al = 27.

1. How much aluminium is there in 100 gm. of (α) clay $Al_2O_3.2SiO_2$, (β) cryolite $Al_2Na_6F_{12}$, (γ) $Al_2P_2O_8H_6Al_2O_6.2H_2O$ turquois?

2. How much sodium is required to reduce 1000 gm. of sodium and aluminium chloride, and how much aluminium is formed?

$$Al_2Cl_6.2NaCl + 6Na = 8NaCl + Al_2.$$

3. How much aluminium is set free on passing 7·339 l. of the vapour of aluminium chloride at 546° C. over heated sodium?

$$Al_2Cl_6 + 6Na = 6NaCl + Al_2.$$

4. What volume of oxygen at 15° C. is required to burn 5 gm. of aluminium?

$$Al_2 + 3O = Al_2O_3.$$

5. How much sulphide is formed on heating 5 gm. of aluminium in sulphur vapour?

$$Al_2 + 3S = Al_2S_3.$$

6. What volume of aluminium (Δ 2·6) must be dissolved in potassium hydrate to make a litre of hydrogen at 12° C.?

$$Al_2 + 2HKO + 2H_2O = 2KAlO_2 + 3H_2.$$

7. On warming 0·5 gm. of aluminium with potassium hydrate 660 ccm. of hydrogen measured over water at 13° C. were evolved. What is the atomic weight of aluminium?

$$Al_2 + 2HKO + 2H_2O = 2KAlO_2 + 3H_2.$$

8. How much potash alum can be made from 1000 gm. of (α) clay, (β) alumina?

$$Al_2O_32SiO_2 + 3H_2SO_4 + K_2SO_4 + 21H_2O = 2SiO_2 + K_2Al_24SO_424H_2O.$$
$$Al_2O_3 + \text{ ,, } \quad \text{ ,, } \quad \text{ ,, } = K_2Al_24SO_4.24H_2O.$$

9. 100 gm. of ammonia-alum are heated (α) alone, how much alumina is left? (β) with lime, what volume of ammonia is given off?

$$(NH_4)_2Al_24SO_4.24H_2O = (NH_4)_2SO_4 + Al_2O_3 + 3H_2SO_4 + 21H_2O.$$
$$(NH_4)_2Al_24SO_424H_2O + CaO = CaSO_4 + 2NH_3 + Al_23SO_4 + 25H_2O.$$

10. Find the formula of a mineral containing alumina 68·31, ferric oxide 3·37, ferrous oxide 2·06, and magnesia 26·26 per cent.

11. What volume of chlorine at 15° C. and 750 mm. is required to convert 100 gm. of alumina into aluminium chloride?

$$Al_2O_3 + 3C + 6Cl = 3CO + Al_2Cl_6.$$

12. The vapour of aluminium chloride is 9·34 times as heavy as air. What is its molecular weight?

13. What does a litre of the vapour of aluminium chloride (Al_2Cl_6) at 300° C. weigh?

14. Steam is passed over 20 gm. of warm aluminium chloride. What volume of hydrogen chloride at 150° C. is formed?

$$Al_2Cl_6 + 3H_2O = Al_2O_3 + 6HCl.$$

15. A gram of aluminium while dissolving in hydrogen chloride gave 1271 ccm. of hydrogen at 10° C. What is the atomic weight of aluminium?

$$Al_2 + 6HCl = Al_2Cl_6 + 3H_2.$$

16. What volume of hydrogen sulphide at 15° C. and 800 mm. is evolved by the action of water upon 10 gm. of aluminium sulphide?

$$Al_2S_3 + 3H_2O = Al_2O_3 + 3H_2S.$$

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17. 20 gm. of cryolite are heated with hydrogen sulphate. What volume of hydrogen fluoride at 20° C. is given off?

$$Na_6Al_2F_{12} + 6H_2SO_4 = 3Na_2SO_4 + Al_23SO_4 + 12HF.$$

18. Find the formula of chiolite which contains aluminium 17·66, sodium 24·97, and fluorine 57·37 per cent.

19. Find a formula for ultramarine which contains aluminium 14·25, silicon 17·49, sodium 16·2, sulphur 14·07, and oxygen 38 per cent.

20. Find a formula for Stourbridge fire-clay, which contains silica 64·1, alumina 23·15, ferrous oxide 1·85, magnesia 0·95, and water 10 per cent.

CHAPTER XXIX.

MAGNESIUM, Mg = 24·4.

1. How much magnesium is there in 1000 gm. of (α) magnesite $MgCO_3$, (β) dolomite, $MgCa2CO_3$, (γ) Epsom salts $MgSO_4.7H_2O$?

2. What is the percentage composition of (α) meerschaum $Mg_2Si_3O_84H_2O$, (β) serpentine $Mg_3Si_2O_72H_2O$?

3. How much magnesium is formed on heating 100 gm. of potassium with magnesium chloride?

$$K_2 + MgCl_2 = 2KCl + Mg.$$

4. What volume of chlorine at 12° C. and 750 mm. is evolved in making 10 gm. of magnesium by electrolysis?

$$MgCl_2 = Mg + Cl_2.$$

5. How much sodium is required to decompose a kilogram of magnesium chloride, and how much magnesium is formed?

$$MgCl_2 + 2Na = 2NaCl + Mg.$$

6. What volume of chlorine at 15° C. and 745 mm. is evolved during the separation of 2 gm. of magnesium from the fused chloride?

$$MgCl_2 = Mg + Cl_2.$$

7. What volume of oxygen at 13° C. is required to burn 7 gm. of magnesium?

$$Mg + O = MgO.$$

8. 40 gm. of magnesium are dissolved in dilute hydrogen chloride. What volume of hydrogen at 21° C. and 380 mm. is evolved?

$$Mg + 2HCl = MgCl_2 + H_2.$$

9. 0·2 gm. of magnesium gave 195·5 ccm. of hydrogen at 13° C. What is the atomic weight of magnesium?

$$Mg + 2HCl = MgCl_2 + H_2.$$

10. What volume of hydrogen measured over water at 14° C. and 760 mm. is set free on dissolving 0·2 gm. of magnesium in acid?

$$Mg + 2HCl = MgCl_2 + H_2.$$

11. 0·1 gm. of magnesium gave 100 ccm. of hydrogen at 12° C. The barometer stood at 758·8 mm., and the column of water in the tube at 250 mm. Find the equivalent of magnesium.

$$mg + hcl = mgcl + h.$$

12. How much crystallized magnesium sulphate can be obtained by dissolving 1000 gm. of magnesite in dilute hydrogen sulphate; and what volume of carbon dioxide is evolved?

$$MgCO_3 + H_2SO_4 + 6H_2O = MgSO_4 7H_2O + CO_2.$$

13. A dolomite contains 12 per cent. of magnesium carbonate. How many kilograms of Epsom salts could be made from 120 kilo. of it?

$$MgCO_3 + H_2SO_4 + 6H_2O = CO_2 + MgSO_4 7H_2O.$$

14. 4 gm. of dolomite when strongly heated gave 937·4 ccm. of carbon dioxide. Find the percentage of calcium and magnesium carbonates in the dolomite.

$$[CaMg]CO_3 = [CaMg]O + CO_2.$$

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15. What volume of nitrogen at 20° C. and 780 mm. will combine with 50 gm. of magnesium?

$$3Mg + 2N = Mg_3N_2.$$

16. Water saturated with carbon dioxide dissolves 25·8 gm. of magnesium carbonate and 0·88 gm. of calcium carbonate per litre. What is the percentage of impurity in the magnesium carbonate thrown down on boiling such a solution of dolomite?

17. A magnesium (Δ 1·74) wire 1 mm. in diameter is burnt in a cylinder of oxygen at 0° C. After cooling, the water rises through a distance equal to the length of wire burnt. Find the radius of the cylinder.

$$Mg + O = MgO.$$

CHAPTER XXX.

ZINC, Zn = 65·4.

1. Find the percentage composition of (α) zinc blende ZnS, (β) calamine $ZnCO_3$.

2. Find the formula of a substance containing zinc 54·17, silicon 11·67, oxygen 26·67, and water 7·5 per cent.

3. A kilogram of (α) calamine (β) blende is roasted to oxide, which is reduced. How much carbon is required, and carbon monoxide by volume evolved?

$$ZnCO_3 = ZnO + CO_2. \qquad ZnS + 3O = ZnO + SO_2.$$
$$ZnO + C = Zn + CO.$$

4. How much zinc white can be made from 1000 gm. of zinc, and what volume of air is required?

$$Zn + O = ZnO.$$

5. What volume of air is required to oxidize 1000 kilo. of zinc blende?

$$2ZnS + 3O_2 = 2ZnO + 2SO_2.$$

6. How many pounds of zinc can be dissolved by 600 lb. of hydrogen sulphate diluted with water?

$$Zn + H_2SO_4 = ZnSO_4 + H_2.$$

7. What volume of hydrogen measured over water at 15° C. and 760 mm. is set free on dissolving 0·5 gm. of zinc in acid?

$$Zn + 2HCl = ZnCl_2 + H_2.$$

8. 0·5 gm. of zinc when dissolved in acid gave 183 ccm. of hydrogen measured over water at 9° C. and 748 mm. Find the equivalent of zinc.

$$zn + hcl = zncl + h.$$

9. 4 l. of chlorine at 30° C. and 770 mm. are passed over heated zinc. How much zinc chloride is formed?

$$Zn + Cl_2 = ZnCl_2.$$

10. 40 gm. of zinc are boiled with potassium hydrate. What volume of hydrogen at 17° C. is evolved?

$$Zn + 2HKO = K_2ZnO_2 + H_2.$$

CADMIUM, Cd = 112.

11. What is the percentage composition of cadmium sulphide CdS?

12. How much crystallized cadmium bromide can be made from 100 gm. of cadmium, and what volume of hydrogen is evolved?

$$Cd + 2HBr + 4H_2O = CdBr_24H_2O + H_2.$$

13. Find the formula of a substance containing zinc 58·56, carbon 4·05, oxygen 25·23, and water 12·16 per cent.

14. A metallic chloride, the vapour of which is 6 times as heavy as air, is found to contain 38·66 per cent. of chlorine. Find the atomic weight of the metal and the formula of the chloride.

15. How much zinc must be dissolved in acid to fill a wedge-shaped gas-bag 1 m. long, 60 ccm. broad, and 34 ccm. deep at the thickest end with hydrogen at 15° C. and 780 mm. ?

$$Zn + 2HCl = ZnCl_2 + H_2.$$

16. Brass consists of 2 parts of copper alloyed with 1 part of zinc. Find an approximate formula for it.

17. A substance contains zinc 53, carbon 38·9, and hydrogen 8·1 per cent. Find the formula of it.

18. Potassium nitrate is boiled with zinc, iron, and potassium hydrate. How much zinc is dissolved during the evolution of 1 l. of ammonia at 10° C. and 730 mm. ?

$$14HKO + 8Zn + 2KNO_3 = 8K_2ZnO_2 + 4H_2O + 2NH_3.$$

CHAPTER XXXI.

MANGANESE, Mn = 55.

1. How much manganese is there in 100 gm. of (α) pyrolusite MnO_2, (β) braunite Mn_2O_3, (γ) manganese blende MnS, (δ) manganese sulphate $MnSO_4 5H_2O$, (ϵ) manganese alum $K_2Mn_2 4SO_4 24H_2O$?

2. 100 gm. of manganous oxide are heated to whiteness with charcoal. How much manganese and what volume of carbon monoxide is formed ?

$$MnO + C = Mn + CO.$$

3. The specific heat of manganese is 0·1217, and from 100 pts. of manganous oxide (MnO) Marignac obtained 212·73 pts. of manganous sulphate ($MnSO_4$). What is the atomic weight of manganese ?

4. According to v. Hauer manganous sulphate ($MnSO_4$) contains 42·392 per cent. of oxygen. What is the atomic weight of manganese ?

5. 481 gm. of manganese dioxide are heated. What volume of oxygen at 15° C. is given off ?

$$3MnO_2 = Mn_3O_4 + O_2.$$

6. What volume of oxygen at 15° C. is obtained on heating 40 gm. of manganese dioxide with hydrogen sulphate?

$$MnO_2 + H_2SO_4 = MnSO_4 + H_2O + O.$$

7. What volume of air is required to oxidize the manganese in 1000 l. of "red liquor" containing 100 gm. of manganous chloride per litre?

$$MnCl_2 + H_2CaO_2 + O = CaCl_2 + H_2O + MnO_2.$$

8. How much manganese dioxide can be made from 1000 l. of "red liquor" containing 0·3 gm. of manganous chloride in 1 ccm.?

$$MnCl_2 + H_2CaO_2 + O = CaCl_2 + H_2O + MnO_2.$$

9. How much *available* oxygen is there in 100 gm. of (α) manganese dioxide, (β) sodium manganate, (γ) potassium permanganate?

$$MnO_2 + H_2SO_4 = MnSO_4 + H_2O + O.$$
$$Na_2MnO_4 + 2H_2SO_4 = MnSO_4 + 2H_2O + Na_2SO_4 + O_2.$$
$$K_2Mn_2O_8 + 3H_2SO_4 = 2MnSO_4 + 3H_2O + K_2SO_4 + 5O.$$

10. What volume of chlorine can be obtained by heating 20 gm. of pyrolusite, containing 17 per cent. of available oxygen, with hydrogen chloride?

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2.$$

11. How much "manganese" containing 85 per cent. of the dioxide is required to make 300 lb. of chlorine?

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2.$$

12. 0·4 gm. of "manganese" distilled with hydrogen chloride evolved sufficient chlorine to set free 1 gm. of iodine from potassium iodide. What is the percentage of real dioxide in the sample?

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2.$$
$$Cl_2 + 2KI = 2KCl + I_2.$$

13. What volume of carbon dioxide is evolved on mixing 7 gm. of manganese dioxide with water, hydrogen oxalate, and hydrogen sulphate?

$$MnO_2 + H_2SO_4 + C_2H_2O_4 = MnSO_4 + 2H_2O + 2CO_2.$$

14. 10 gm. of "manganese" mixed with hydrogen sulphate oxidized 10·953 gm. of hydrogen oxalate. What is the percentage of dioxide in the ore?

$$MnO_2 + C_2H_2O_4.2H_2O + H_2SO_4 = MnSO_4 + 4H_2O + 2CO_2.$$

15. 4·9435 gm. of "manganese" warmed with hydrogen oxalate and sulphate gave 2·18 gm. of carbon dioxide. Find the percentage of real dioxide in the sample?

$$MnO_2 + C_2H_2O_4 2H_2O + H_2SO_4 = MnSO_4 + 4H_2O + 2CO_2.$$

16. 100 gm. of sodium manganate are heated in steam. What volume of oxygen at 13° C. is set free?

$$Na_2MnO_4 + H_2O = 2HNaO + MnO_2 + O.$$

17. 3 gm. of potassium permanganate are dissolved in a litre of water. How much available oxygen does 1 ccm. of the solution contain?

$$K_2Mn_2O_8 + 3H_2SO_4 = K_2SO_4 + MnSO_4 + 3H_2O + 5O.$$

18. 0·2961 gm. of crystallized hydrogen oxalate required 47 ccm. of a solution of potassium permanganate to oxidize it. How much permanganate was there in 1 l. of the solution?

$$K_2Mn_2O_8 + 5C_2H_2O_4 2H_2O + 3H_2SO_4 = K_2SO_4 + MnSO_4 + 18H_2O + 10CO_2.$$

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19. How much manganese dioxide is required to give 2·7 l. of oxygen at 14° C. and 754 mm.?

$$3MnO_2 = Mn_3O_4 + O_2.$$

20. A gram of partially dried hydrogen oxalate gave 492 ccm. of carbon dioxide measured over water at 20° C. and 757·4 mm. Find the percentage of water still left in the oxalate.

$$C_2H_2O_4 + MnO_2 + H_2SO_4 = MnSO_4 + 2H_2O + 2CO_2.$$

CHAPTER XXXII.

IRON, Fe = 56.

1. How much iron is there in 100 gm. of (α) magnetic iron ore Fe_3O_4, (β) hematite Fe_2O_3, (γ) brown hematite $2Fe_2O_3.3H_2O$, (δ) spathic iron ore $FeCO_3$, (ϵ) iron pyrites FeS_2, (ζ) magnetic pyrites Fe_2S_4?

2. How many tons of coke containing 97 per cent. of carbon are required to reduce 388 tons of hematite?

$$Fe_2O_3 + 3C = 3CO + Fe_2.$$

3. How many cubic metres of carbon monoxide at 1200° C. are evolved in making a ton of iron from ferrous carbonate?

$$FeCO_3 + 2C = 3CO + Fe.$$

4. What volume of hydrogen at 13° C. and 780 mm. is required to reduce 63 gm. of ferric oxide?

$$Fe_2O_3 + 6H = 3H_2O + Fe_2.$$

5. What volume of hydrogen at 14° C. and 740 mm. is required to reduce 100 gm. of ferric oxide?

$$Fe_2O_3 + 6H = 3H_2O + Fe_2.$$

6. From how many litres of air at 13° C. is the oxygen removed by a kilogram of iron in rusting?

$$2Fe + 3O = Fe_2O_3.$$

7. What volume of oxygen is required to burn a gram of iron?

$$3Fe + 4O = Fe_3O_4.$$

8. An iron (Δ 7·7) wire 1 mm. in diameter is burnt in a cylinder of oxygen. After again cooling to 0° C. the water rises through a height equal to the length of wire burnt. Find the radius of the cylinder.

$$3Fe + 4O = Fe_3O_4.$$

9. 14 gm. of iron are dissolved in hydrogen chloride. What volume of hydrogen at 13° C. and mass of crystallized ferrous chloride is formed?

$$Fe + 2HCl + 4H_2O = FeCl_24H_2O + H_2.$$

10. During the solution of a gram of iron 389·74 ccm. of hydrogen at 14° C. and 820 mm. were evolved. Find the equivalent of iron.

$$fe + hcl = fecl + h.$$

11. How many kilograms of iron must be heated in steam to make hydrogen at − 30° C. and 480 mm. sufficient to fill a balloon containing 1000 cubic metres?

$$3Fe + 4H_2O = Fe_3O_4 + 4H_2.$$

12. According to Berzelius 1·586 gm. of iron form 2·265 gm. of ferric oxide. What is the atomic weight of iron?

$$2Fe + 3O = Fe_2O_3.$$

13. How much ferrous oxide can be made by heating 147 gm. of ferrous oxalate in hydrogen?

$$FeC_2O_4 2H_2O = 2H_2O + CO_2 + CO + FeO.$$

14. What is the vapour density compared to air of (α) ferropentacarbonyl $Fe(CO)_5$ and (β) diferroheptacarbonyl $Fe_2(CO)_7$?

15. Calculate the percentage composition of the carbides of iron (α) Fe_4C, (β) Fe_3C.

16. Find the formula of a salt containing iron 14, iodine 63·5, and water 22·5 per cent.

17. Find the formula of a liquid containing iron 28·57 %, carbon 30·61 %, and oxygen 40·82 %.

18. A litre of the vapour of ferric chloride reduced by calculation to 0° C. and 760 mm. weighs 14·56 gm. What is its molecular weight?

19. What volume of carbon monoxide at 17° C. is set free on heating 10 gm. of diferroheptacarbonyl to 80° C.?

$$Fe_2(CO)_7 = Fe + Fe(CO)_5 + 2CO.$$

20. Steam is passed over 9·7 gm. of ferrous chloride heated in a tube. What does the resulting hydrogen measure over water at 20° C. and 700mm.?

$$3FeCl_2 + 4H_2O = Fe_3O_4 + 6HCl + H_2.$$

21. What volume of sulphur dioxide at 10° C. is required to reduce a boiling solution of ferric chloride containing 437 gm. of iron?

$$Fe_2Cl_6 + 2H_2O + SO_2 = 2FeCl_2 + 2HCl + H_2SO_4.$$

22. How much sulphur precipitates on passing 1·7 l. of hydrogen sulphide at 17° C. through a solution of ferric chloride?

$$Fe_2Cl_6 + H_2S = 2FeCl_2 + 2HCl + S.$$

23. 10 ccm. of a solution of sodium nitrate boiled with ferrous and hydrogen chlorides gave 50 ccm. of nitric oxide at 17° C. and 740 mm. What amount of sodium nitrate was there in 1 ccm. of the solution?

$$2NaNO_3 + 6FeCl_2 + 8HCl = 4H_2O + 3Fe_2Cl_6 + 2NaCl + 2NO.$$

24. Find the formula of a substance containing iron 19·94, sulphur 17·09, oxygen 34·17, and water 28·8 per cent.

25. Ammonia is added to a solution of 137 gm. of crystallized ferric nitrate and the precipitate is dried. How many grams does it weigh?

$$Fe_2 6NO_3 . 18H_2O + 6NH_3 = 15H_2O + 6NH_4NO_3 + Fe_2O_3.$$

26. Iron nitride, obtained by heating ferrous chloride in ammonia, contains 9·3 per cent. of nitrogen. Find the formula of it.

27. Find the formula of a salt containing iron 28, sulphur 24, and oxygen 48 per cent.

28. Crystallized ferric and ammonium sulphate and ferrous and ammonium sulphate each contains $\frac{1}{7}$ of its mass of iron. Find the two formulæ.

29. 1463 gm. of crystallized ferrous sulphate are required. How much iron must be dissolved in dilute hydrogen sulphate, and what volume of hydrogen at 13° C. is evolved?

$$Fe + H_2SO_4 + 7H_2O = FeSO_4 7H_2O + H_2.$$

30. What volume of hydrogen sulphide at 11° C. is evolved on dissolving 347 gm. of ferrous sulphide in hydrogen chloride?

$$FeS + 2HCl = FeCl_2 + H_2S.$$

31. 489 gm. of ferrous sulphide are dissolved in hydrogen sulphate. What volume of hydrogen sulphide at 17° C. is evolved?

$$FeS + H_2SO_4 = FeSO_4 + H_2S.$$

32. What volume of sulphur dioxide at 39° C. can be obtained by passing air over 100 gm. of red-hot ferrous disulphide?

$$2FeS_2 + 11O = Fe_2O_3 + 4SO_2.$$

33. How many tons of hydrogen sulphate can be made from 10 tons of pyrites?

$$2FeS_2 + 15O + 4H_2O = Fe_2O_3 + 4H_2SO_4.$$

34. How much iron is converted from a ferrous to a ferric salt by one gram of potassium (α) permanganate, (β) dichromate?

$$10FeSO_4 + K_2Mn_2O_8 + 8H_2SO_4 = 5Fe_2 3SO_4 + K_2SO_4 + MnSO_4 + 8H_2O.$$
$$6FeSO_4 + K_2Cr_2O_7 + 7H_2SO_4 = 3Fe_2 3SO_4 + K_2SO_4 + Cr_2 3SO_4 + 7H_2O.$$

35. 8 gm. of potassium (α) permanganate, (β) dichromate are dissolved in a litre of water. To how much iron is 1 ccm. of each solution equivalent?

$$10FeSO_4 + K_2Mn_2O_8 + \&c.$$
$$6FeSO_4 + K_2Cr_2O_7 + \&c.$$

36. 0·2 gm. of levigated iron dissolved in hydrogen sulphate required 30 ccm. of a solution of permanganate containing 3 gm. of the salt per litre. What is the percentage of iron?

$$10FeSO_4 + K_2Mn_2O_8 + \&c.$$

37. A solution of 0·985 gm. of black-band ironstone required 55·5 ccm. of a solution of permanganate containing 3 gm. of the salt per litre. What is the percentage of iron in the ore?

$$10FeSO_4 + K_2Mn_2O_8 + \&c.$$

38. 3 ccm. of a solution of ferrous sulphate required 22·5 ccm. of a solution of dichromate containing 4·9 gm. of the salt per litre. How much iron is there in 1 ccm. of the solution?

$$6FeSO_4 + K_2Cr_2O_7 + \&c.$$

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39. Some steel-grey crystals in a Carinthian blast-furnace were found to contain iron 76·23, and oxygen 23·76 per cent. Find the formula of the oxide.

40. Find the formula of a salt containing iron 43·75, sulphur 18·75, and oxygen 37·5 per cent.

41. 1·25 gm. of ferric oxide, when reduced by hydrogen and dissolved in dilute acid, gave 382·6 ccm. of hydrogen measured over water at 17° C. and 750 mm. Find the atomic weight of iron.

$$Fe_2O_3 + 6H = 3H_2O + Fe_2.$$
$$2Fe + 4HCl = 2FeCl_2 + 2H_2.$$

42. 10 gm. of ferrous oxalate heated in hydrogen gave a mixture of iron and ferrous oxide. The product dissolved in acid gave 300 ccm. of hydrogen measured over water at 10° C. Find the percentage of iron and of ferrous oxide in the residue.

$$FeC_2O_4 2H_2O = 2H_2O + CO_2 + CO + FeO.$$
$$FeC_2H_4 2H_2O = 2H_2O + 2CO_2 + Fe.$$
$$Fe + 2HCl = FeCl_2 + H_2.$$

43. 10·758 gm. of a sample of Swedish steel gave (α) 0·2872 gm. of carbon dioxide, (β) 0·004 gm. of barium sulphate, (γ) 0·011 gm. of graphite, (δ) 0·006 gm. of silica, and (ε) 0·018 gm. of manganoso-manganic oxide. Calculate the percentage composition.

CHAPTER XXXIII.

NICKEL, Ni = 58.

1. What volume of carbon monoxide at 1200° C. is set free in reducing 764 gm. of nickelous oxide?

$$NiO + C = Ni + CO.$$

2. What volume of hydrogen at 17° C. is required to reduce 10 gm. of nickelous oxide?

$$NiO + H_2 = H_2O + Ni.$$

3. How much mercuric oxide is required to precipitate 20 gm. of nickel as nickelous oxide?

$$NiCl_2 + HgO = HgCl_2 + NiO.$$

4. What volume of nickel tetracarbonyl at 43° C. can be formed from 11·6 gm. of nickel?

$$Ni + 4CO = Ni(CO)_4.$$

5. 200 ccm. of nickel tetracarbonyl at 52° C. are heated, how much nickel and what volume of carbon monoxide at 180° C. are set free?

$$Ni(CO)_4 = Ni + 4CO.$$

6. A thin hot sheet of iron a decimetre square is dipped into petroleum containing 12 ccm. of liquid nickel tetracarbonyl (Δ 1·3) in solution. How thick is the deposited nickel (Δ 8·6)?

$$Ni(CO)_4 = Ni + 4CO.$$

7. Find the percentage composition of potassium and nickel nitrite $NiK_4(NO_2)_6$.

8. What is the formula of a substance containing nickel 31·15, hydrogen 3·18, nitrogen 14·84, sulphur 16·95, and oxygen 33·88 per cent.?

COBALT, Co = 59.

9. Find the formula of a substance containing cobalt 35·54, arsenic 45·18, and sulphur 19·28 per cent.

10. What volume of hydrogen at 15° C. is required to reduce 100 gm. of cobaltic oxide?

$$Co_2O_3 + 6H = 3H_2O + 2Co.$$

11. 400 gm. of cobaltous oxalate are heated. What volumes of carbon dioxide and of steam at 1500° C. and how much cobalt is formed?

$$CoC_2O_4 2H_2O = Co + 2H_2O + 2CO_2.$$

12. What volume of chlorine at 14° C. is required to precipitate 1000 gm. of cobalt in presence of barium carbonate as cobaltic oxide?

$$2CoCl_2 + 3BaCO_3 + Cl_2 = 3BaCl_2 + 3CO_2 + Co_2O_3.$$

13. Calculate the percentage composition of potassium cobalticyanide ($K_6Co_2C_{12}N_{12}$).

14. Find the percentage composition of roseo-cobaltic chloride ($Co_2Cl_6.10NH_3.H_2O$).

15. What volume of bromine (Δ 3) is required to precipitate 10 gm. of cobalt in presence of barium carbonate as cobaltic oxide?

$$2CoCl_2 + 3BaCO_3 + Br_2 = 2BaCl_2 + BaBr_2 + 3CO_2 + Co_2O_3.$$

16. What volume of chlorine at 26° C. and 740 mm. is given off on boiling 10 gm. of cobaltic oxide with hydrogen chloride?

$$Co_2O_3 + 6HCl = 3H_2O + 2CoCl_2 + Cl_2.$$

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17. Find the formula of Schreibersite which contains iron 60·16 nickel 25·96, and phosphorus 13·88 per cent.

18. What is the formula of a substance containing cobalt 26·69, arsenic 25, oxygen 21·31, and water 24 per cent.?

19. 0·7 gm. of cobalt gave 292·3 ccm. of hydrogen measured over water at 20° C. and 756 mm. What is the atomic weight of the metal?

$$Co + 2HCl = CoCl_2 + H_2.$$

20. 1·4 gm. of impure cobalt, dissolved in acid and mixed with potassium acetate and nitrite, gave a precipitate weighing 9·2 gm. What percentage of cobalt was there in the impure metal?

$$2CoCl_2 + 2HC_2H_3O_2 + 12KNO_2 + O = 4KCl + H_2O + 2KC_2H_3O_2 + Co_2K_6(NO_2)_{12}.$$

CHAPTER XXXIV.

CHROMIUM, Cr = 52.

1. Find the percentage composition of (α) chrome ironstone (Cr_2O_3FeO), (β) chromic oxide (Cr_2O_3).

2. 163 gm. of chromic oxide are heated with sugar-charcoal. How much chromium is formed, and what volume of carbon monoxide at 26° C. is evolved?

$$Cr_2O_3 + 3C = 3CO + Cr_2.$$

3. How many grams of sodium in vapour must be passed over 147 gm. of chromic chloride and how much chromium is formed?

$$Cr_2Cl_6 + 6Na = 6NaCl + Cr_2.$$

4. How much zinc is required to reduce 400 gm. of chromic chloride mixed with potassium and sodium chlorides, and how much chromium is set free?

$$Cr_2Cl_6 + 3\,Zn = 3ZnCl_2 + Cr_2.$$

5. 100 gm. of mercurous chromate are heated. How much chromic oxide is formed and what volume of oxygen is given off?

$$2Hg_2CrO_4 = 4Hg + Cr_2O_3 + 5O.$$

6. 1000 gm. of potassium dichromate are dissolved and reduced by sulphur dioxide. On adding ammonia and heating the precipitate how much chromic oxide is formed?

$$K_2Cr_2O_7 + 3SO_2 + H_2SO_4 = K_2SO_4 + H_2O + Cr_23SO_4.$$
$$Cr_23SO_4 + 6(NH_4)HO = 3H_2O + 3(NH_4)_2SO_4 + Cr_2O_3.$$

7. A substance contains chromic oxide 54·67, and water 45·33 per cent. Find its formula.

8. Find the formula of a substance containing potassium 27·07, chromium 12, carbon 16·62, and oxygen 44·31 per cent.

9. How much chromic sulphide can be obtained from 100 gm. of chromic oxide, and what volume of carbon dioxide at 210° C. is evolved?

$$2Cr_2O_3 + 3CS_2 = 2Cr_2S_3 + 3CO_2.$$

10. 10 gm. of lead chromate are heated with fluorspar and hydrogen sulphate. What volume of chromium hexafluoride at 21° C. is obtained?

$$PbCrO_4 + 3CaF_2 + 4H_2SO_4 = 4H_2O + PbSO_4 + 3CaSO_4 + CrF_6.$$

11. How many times is the vapour of chromium hexafluoride (CrF_6) heavier than air?

12. What volume of chlorine at 17° C. and 800 mm. is required to convert 407 gm. of chromic oxide into chromic chloride?

$$Cr_2O_3 + 6Cl + 3C = 3CO + Cr_2Cl_6.$$

13. 21 l. of chlorine at 12° C. are passed over a heated mixture of chromic oxide and charcoal. How much chromic chloride is formed?

$$6Cl + Cr_2O_3 + 3C = 3CO + Cr_2Cl_6.$$

14. What volume of hydrogen at 15° C. is required to reduce 100 gm. of chromic to chromous chloride?

$$Cr_2Cl_6 + H_2 = 2HCl + 2CrCl_2.$$

15. According to Péligot 100 gm. of chromous chloride ($CrCl_2$) contain 57·5 gm. of chlorine. What is the atomic weight of chromium?

16. According to Siewert 36·865 parts of chromic chloride give 100 pts. of silver chloride. Find the atomic weight of chromium?

$$Cr_2Cl_6 + 6AgNO_3 = Cr_26NO_3 + 6AgCl.$$

17. How much chrome-alum is formed by mixing a solution of 1500 gm. of potassium dichromate with hydrogen sulphate and alcohol and crystallizing?

$$K_2Cr_2O_7 + 3C_2H_6O + 4H_2SO_4 + 17H_2O = 3C_2H_4O + K_2Cr_24SO_424H_2O.$$

18. Calculate the percentage composition of chromium (α) monoxide CrO, (β) dioxide CrO_2.

CHROMIUM TRIOXIDE, $CrO_3 = 100$.

19. How many tons of potassium dichromate can be made from 10 tons of chrome iron-stone?

$$2FeCr_2O_4 + 3K_2CO_3 + CaO + 7O = 3K_2CrO_4 + CaCrO_4 + Fe_2O_3 + 3CO_2.$$
$$CaCrO_4 + K_2SO_4 = CaSO_4 + K_2CrO_4.$$
$$4K_2CrO_4 + 2H_2SO_4 = 2K_2SO_4 + 2H_2O + 2K_2Cr_2O_7.$$

20. What volume of hydrogen sulphate (Δ 1·84) must be mixed with 100 ccm. of solution of potassium dichromate (cont. 100 gm.

water and 10 gm. salt) that the acid formed may have the composition (α) $H_2SO_4H_2O$, (β) 65 % of real acid, in which chromium trioxide is nearly insoluble?

$$K_2Cr_2O_7 + H_2SO_4 = K_2SO_4 + H_2O + 2CrO_3.$$

21. How much ammonium dichromate can be made from 1000 gm. of potassium dichromate?

$$K_2Cr_2O_7 + H_2SO_4 = K_2SO_4 + H_2O + 2CrO_3.$$
$$2CrO_3 + 2NH_3 + H_2O = (NH_4)_2Cr_2O_7.$$

22. What volume of oxygen at 30° C. is given off on heating 70 gm. of chromium trioxide?

$$2CrO_3 = Cr_2O_3 + 3O.$$

23. How much potassium dichromate must be heated with hydrogen sulphate to make 15 l. of oxygen at 15° C.?

$$K_2Cr_2O_7 + 4H_2SO_4 = K_2SO_4 + Cr_23SO_4 + 4H_2O + 3O.$$

24. 10 gm. of chromium trioxide are heated with hydrogen chloride. What volume of chlorine at 26° C. and 800 mm. is evolved?

$$2CrO_3 + 12HCl = 6H_2O + Cr_2Cl_6 + 3Cl_2.$$

25. Find the percentage composition of potassium chlorochromate ($KClCrO_3$).

26. Find the formula of a substance containing potassium 19·84, chromium 39·57, and oxygen 40·58 per cent.

27. 10 gm. of chromium trioxide when heated left 7·6 gm. of chromic oxide. What is the atomic weight of chromium?

$$2CrO_3 = Cr_2O_3 + 3O.$$

28. According to Berlin 100 gm. of lead nitrate gave 97·576 gm. of lead chromate. Find the atomic weight of chromium.

$$Pb2NO_3 + K_2CrO_4 = 2KNO_3 + PbCrO_4.$$

29. How much available oxygen is there in 1 gm. of (α) chromium trioxide, (β) potassium dichromate?

$$2CrO_3 + 3H_2SO_4 = Cr_23SO_4 + 3H_2O + 3O.$$
$$K_2Cr_2O_7 + 4H_2SO_4 = Cr_23SO_4 + K_2SO_4 + 4H_2O + 3O.$$

30. 10 gm. of potassium dichromate are dissolved in a litre of water. 1 ccm. of the solution (α) contains how much available oxygen, (β) oxidizes how much iron, (γ) precipitates how much lead?

$$K_2Cr_2O_7 + 4H_2SO_4 = Cr_23SO_4 + K_2SO_4 + 4H_2O + 3O.$$
$$K_2Cr_2O_7 + 6FeSO_4 + 7H_2SO_4 = Cr_23SO_4 + K_2SO_4 + 3Fe_23SO_4 + 7H_2O.$$
$$K_2Cr_2O_7 + 2Pb2NO_3 + H_2O = 2KNO_3 + 2HNO_3 + 2PbCrO_4.$$

31. What volume of sulphur dioxide at 15° C. and 780 mm. is required to reduce 47 gm. of potassium dichromate?

$$K_2Cr_2O_7 + 3SO_2 + H_2SO_4 = Cr_2(SO_4)_3 + K_2SO_4 + H_2O.$$

32. 20 gm. of potassium dichromate are heated with hydrogen oxalate and sulphate. What volume of carbon dioxide at 30° C. is given off?

$$K_2Cr_2O_7 + 5H_2SO_4 + 3C_2H_2O_4 = 2HKSO_4 + Cr_2(SO_4)_3 + 7H_2O + 6CO_2.$$

33. What volume of nitrogen at 13° C. and 780 mm. is evolved on heating 126 gm. of ammonium dichromate, and how much chromic oxide is left?

$$(NH_4)_2Cr_2O_7 = Cr_2O_3 + 4H_2O + N_2.$$

34. What volume of nitrogen measured over water at 30° C. and 740 mm. is evolved on heating 70 gm. of ammonium dichromate?

$$(NH_4)_2Cr_2O_7 = Cr_2O_3 + 4H_2O + 2N.$$

35. What volume of nitrogen at 13° C. and 740 mm. is evolved on boiling 100 gm. of potassium dichromate with equal quantities of ammonium and sodium nitrates?

$$K_2Cr_2O_7 + 4NH_4NO_3 + 4NaNO_3 = 5H_2O + 2KNO_3 + 4NaNO_3 + H_6Cr_2O_6 + 4N.$$

36. What volume of chromyl dichloride (Δ 1·7) can be obtained by distilling 23 gm. of sodium chloride with potassium dichromate and hydrogen sulphate?

$$4NaCl + K_2Cr_2O_7 + 3H_2SO_4 = 2Na_2SO_4 + K_2SO_4 + 3H_2O + 2CrO_2Cl_2.$$

37. The vapour of 20 ccm. of chromyl dichloride (Δ 1·7) is passed through a red-hot tube. How much chromic oxide, and what volumes of oxygen and of chlorine at 6° C. are formed?

$$2CrO_2Cl_2 = Cr_2O_3 + 4Cl + O.$$

38. How many times is the vapour of chromyl dichloride (CrO_2Cl_2) heavier than air?

CHAPTER XXXV.

TIN, Sn = 118.

1. Find the percentage composition of tinstone (SnO_2).

2. Find the formula of tin pyrites, which contains copper 29·53, iron 13·07, tin 27·53, and sulphur 29·86 per cent.

3. How much charcoal is required to reduce 1000 kilo. of tinstone, and what volume of carbon monoxide at 15° C. is set free?

$$SnO_2 + 2C = Sn + 2CO.$$

4. 100 gm. of tin were heated with hydrogen nitrate. The stannic oxide after ignition weighed 127·1 gm. What is the atomic weight of tin?

$$Sn + O_2 = SnO_2.$$

5. 10 gm. of tin were boiled with hydrogen chloride; when 1·12 l. of hydrogen had been given off the tin was found to weigh 4·1 gm. What is the atomic weight of tin?

$$Sn + 2HCl = SnCl_2 + H_2.$$

6. What volume of air at 13° C. is required to convert 590 gm. of tin into the dioxide?

$$Sn + O_2 = SnO_2.$$

7. 17 gm. of tin were dissolved in sodium hydrate. What volume of hydrogen at 15° C. was evolved?

$$Sn + 2HNaO + H_2O = Na_2SnO_3 + 2H_2.$$

8. 200 gm. of tin are dissolved in hydrogen chloride. How much sodium carbonate must be added, and how much stannous oxide can be obtained?

$$SnCl_2 + Na_2CO_3 = 2NaCl + CO_2 + SnO.$$

9. Find the percentage composition of stannous metastannate ($SnH_8Sn_5O_{15}$)?

10. Find the formula of a substance containing sodium 16·2, tin 41·56, oxygen 16·9, and water 25·34 per cent.

11. Find the formula of a substance containing hydrogen 0·84, tin 74·06, and oxygen 25·1 per cent.

12. How much "tin-salts," and what volume of hydrogen measured over water at 13° C. and 780 mm. are formed on dissolving 236 gm. of tin in hydrogen chloride?

$$Sn + 2HCl + 2H_2O = SnCl_2 2H_2O + H_2.$$

13. 40 gm. of bromine are converted into hydrogen bromide, which is passed over heated tin. What volume of hydrogen at 15° C. is set free?

$$2HBr + Sn = SnBr_2 + H_2.$$

14. What volume of gaseous hydrogen chloride at 60° C. is required to convert 50 gm. of tin into stannous chloride?

$$Sn + 2HCl = SnCl_2 + H_2.$$

15. Find the formula of a substance containing nitrogen 7·63, hydrogen 2·17, tin 32·16, and chlorine 58·03 per cent.

16. What volume of chlorine at 26° C. is absorbed in converting 1000 gm. of tin into the tetrachloride?

$$Sn + 4Cl = SnCl_4.$$

17. The vapour of stannic chloride is 9·199 times as heavy as air, and that of stannous chloride 13·08 times as heavy. Find the double-densities of these vapours referred to hydrogen.

18. Find the formula of a substance containing tin 64·84 and sulphur 35·16 per cent.

19. What volume of hydrogen sulphide at 26° C. is required to throw down the tin from a solution of 110 gm. of "tin-salts"?

$$SnCl_2 2H_2O + H_2S = SnS + 2HCl + 2H_2O.$$

20. 9 gm. of tin are dissolved in aqua regia. What volume of hydrogen sulphide at 15° C. and 770 mm. is required to precipitate them?

$$SnCl_4 + 2H_2S = 4HCl + SnS_2.$$

21. 4 gm. of tin are heated in 200 ccm. of hydrogen sulphide at 10° C. and 740 mm. How much does the tin increase in mass?

$$Sn + H_2S = H_2 + SnS.$$

22. 10 ccm. of a solution of stannous chloride mixed with excess of ferric chloride required 47 ccm. of a solution of potassium permanganate containing 3 gm. of the salt per litre? How much tin was there in 1 ccm. of the solution?

$$SnCl_2 + Fe_2Cl_6 = SnCl_4 + 2FeCl_2.$$
$$K_2Mn_2O_8 + 10FeCl_2 + \&c.$$

CHAPTER XXXVI.

LEAD, Pb = 207.

1. Find the percentage of lead in (α) galena PbS, (β) cerussite $PbCO_3$, (γ) anglesite $PbSO_4$.

2. 1200 kilo. of galena when roasted are converted half into oxide and half into sulphate. How much unaltered galena is required? How much lead and what volume of sulphur dioxide at 15° C. are formed?

$$4PbS + 14O = 2PbSO_4 + 2PbO + 2SO_2.$$
$$2PbSO_4 + 2PbS = 4Pb + 4SO_2.$$
$$2PbO + PbS = 3Pb + SO.$$

3. 846 kilo. of cerussite are roasted to litharge. How much carbon is required to reduce it? How much lead and what volume of carbon monoxide at 13° C. is formed?

$$PbCO_3 = PbO + CO_2. \qquad PbO + C = Pb + CO.$$

4. How much litharge can be obtained from 40·5 kilo. of lead, and what volume of oxygen is absorbed in the process?

$$Pb + O = PbO.$$

5. What volume of air is required to convert 37·1 kilo. of lead into litharge?

$$Pb + O = PbO.$$

6. Berzelius found that 100 gm. of litharge (PbO) contain 7·1724 gm. of oxygen. Find the atomic weight of lead.

7. What volume of hydrogen at 39° C. is required to reduce 74 gm. of litharge?

$$PbO + H_2 = H_2O + Pb.$$

8. How much silica must be fused with 1000 gm. of litharge to form lead silicate?

$$PbO + SiO_2 = PbSiO_3.$$

9. What volume of oxygen at 13° C. is absorbed in forming 1000 gm. of red-lead?

$$3Pb + 4O = Pb_3O_4.$$

10. How much red-lead must be heated to give 472 ccm. of oxygen at 21° C. and 780 mm.?

$$Pb_3O_4 = 3PbO + O.$$

11. According to Dumas 100 gm. of red-lead when heated give 2·4 gm. of oxygen. Find the formula of red-lead.

$$(PbO)_n(PbO_2)_m = (PbO)_{m+n} + O_m.$$

12. How much lead dioxide can be obtained from 20 gm. of lead nitrate?

$$Pb2NO_3 + CaOCl_2 + H_2O = 2HCl + Ca2NO_3 + PbO_2.$$

13. Find the formula of Cassel yellow, which contains lead 90·05, chlorine 3·86, and oxygen 6·09 per cent.

14. Lead iodide is soluble in 190 times its mass of hot water. How much potassium iodide and lead nitrate must be dissolved in 250 ccm. of water that the precipitate may redissolve on boiling?

$$Pb2NO_3 + 2KI = 2KNO_3 + PbI_2.$$

15. 5 gm. of lead chloride gave 5·16 gm. of silver chloride. What is the atomic weight of lead?

$$PbCl_2 + 2AgNO_3 = Pb2NO_3 + 2AgCl.$$

16. 100 gm. of lead nitrate are heated. What volume of nitrogen tetroxide at 150° C. and 730 mm. is evolved?

$$Pb2NO_3 = PbO + O + 2NO_2.$$

17. According to Stas, 100 gm. of lead form 159·9703 gm. of lead nitrate. What is the atomic weight of lead?

$$Pb + 2HNO_3 = H_2 + Pb2NO_3.$$

18. Find the formula of a substance containing carbon 7·96, hydrogen 0·99, oxygen 10·61, lead 68·66, and chlorine 11·79 per cent.

19. Find the percentage composition of lead chromate, $PbCrO_4$.

20. A substance contains lead monoxide 76·69, and chromium trioxide 23·31 per cent. Find its formula.

21. Water from a leaden cistern 3 m. by 2 m. by 1 m. gave on evaporation with hydrogen sulphate 113 gm. of lead sulphate $PbSO_4$. Find the percentage of lead in the water.

22. 487 gm. of lead sulphate are boiled with sodium carbonate. How much lead carbonate is formed?

$$PbSO_4 + Na_2CO_3 = Na_2SO_4 + PbCO_3.$$

23. 47 gm. of litharge are dissolved in sodium hydrate. What volume of hydrogen sulphide at 17° C. and 790 mm. is required to precipitate them?

$$PbO + H_2S = H_2O + PbS.$$

24. What volume of carbon dioxide at 83° C. and 713 mm. is evolved on heating 69 gm. of lead carbonate?

$$PbCO_3 = PbO + CO_2.$$

25. Find the percentage of lead in crystallized lead acetate $Pb(C_2H_3O_2)_2 3H_2O$.

26. How much litharge and what volume of pyroligneous acid (Δ 1·052), containing 40 per cent. of real acid, is required to form a kilogram of lead acetate?

$$PbO + 2HC_2H_3O_2 + 2H_2O = Pb(C_2H_3O_2)_2 3H_2O.$$

27. 1000 gm. of lead carbonate are dissolved in acetic acid. How much lead acetate and what volume of carbon dioxide at 14° C. and 740 mm. is formed?

$$PbCO_3 + 2HC_2H_3O_2 + 2H_2O = Pb(C_2H_3O_2)_2 3H_2O + CO_2.$$

28. What volume of carbon dioxide at 26° C. is evolved on dissolving 487 gm. of "white-lead" in hydrogen nitrate?

$$PbH_2O_2 2PbCO_3 + 6HNO_3 = 4H_2O + 3Pb2NO_3 + 2CO_2.$$

29. Carbon monoxide is led over 100 gm. of hot lead chloride. What volume of carbonyl chloride at 15° C. is formed?

$$PbCl_2 + CO = Pb + COCl_2.$$

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30. 100 gm. of "white-lead" boiled with dilute hydrogen nitrate gave 6 l. of carbon dioxide at 15° C. Find the percentage of lead carbonate, lead hydrate, and impurity in the sample.

$$PbH_2O_2 2PbCO_3 + 6HNO_3 = 3Pb2NO_3 + 4H_2O + 2CO_2.$$

31. Find the formula of a substance containing lead 77·53, carbon 17·98, and hydrogen 4·49 per cent.

32. What volume is occupied by the vapour of 4 gm. of plumbic ethide $Pb(C_2H_5)_4$ measured at 300° C. and 740 mm.?

CHAPTER XXXVII.

Copper, Cu = 63·3.

1. What is the percentage composition of (α) mysorin $CuCO_4$, (β) malachite $CuCO_3.H_2CuO_2$, (γ) azurite $H_2CuO_2 2CuCO_3$.

2. Find the formula of a substance containing copper 36·11, silicon 15·97, oxygen 27·38, and water 20·54 per cent.

3. 100 gm. of cupric sulphate are warmed with potassium hydrate and grape-sugar. How much cuprous oxide precipitates?

$$2CuSO_4 5H_2O + 4HKO = 2K_2SO_4 + 12H_2O + O + Cu_2O.$$

4. 70 gm. of cuprous chloride in hydrogen chloride are poured into sodium hydrate. How much cuprous hydrate precipitates?

$$4Cu_2Cl_2 + 8HNaO = 8NaCl + 3H_2O + 4Cu_2O.H_2O.$$

5. How much cupric oxide is formed on heating 1467 gm. of copper in air, and what volume of air is required?

$$Cu + O = CuO.$$

6. 1·3305 gm. of copper when heated in oxygen gave 1·6675 gm. of cupric oxide. What is the atomic weight of copper?

$$Cu + O = CuO.$$

7. 10 l. of hydrogen at 30° C. are passed over hot cupric oxide. How much copper is set free, and what volume of steam at 300° C. is formed?

$$CuO + H_2 = Cu + H_2O.$$

8. A spiral of copper wire is heated by electricity in a litre of air at 15° C. How much copper oxide is formed?

$$Cu + O = CuO.$$

9. 100 gm. of copper turnings are warmed with potassium chlorate and hydrogen chloride. When three-fourths of the copper is dissolved the solution is poured into water. How much cuprous chloride precipitates?

$$Cu_2 + Cl_2 = Cu_2Cl_2.$$

10. 40 gm. of cupric chloride are dissolved in ammonia and digested on metallic copper. How much copper dissolves and how much cuprous chloride is formed?

$$CuCl_2.2H_2O + Cu = Cu_2Cl_2 + 2H_2O.$$

11. The vapour of cuprous chloride is 6·93 times as heavy as air. Find its double density referred to hydrogen.

12. What volume of chlorine at 13° C. and 740 mm. is absorbed in converting 100 gm. of copper into cupric chloride?

$$Cu + Cl_2 = CuCl_2.$$

13. Find the formula of a body containing cupric oxide 53·6, cupric chloride 30·2, and water 16·2 per cent.

14. Find the formula of a substance containing copper 56·12, sulphur 7·09, oxygen 24·82, and water 11·97 per cent.

15. What volume of hydrogen sulphide at 30° C. and 800 mm. is required to throw down the copper from a solution of 100 gm. of blue vitriol?

$$CuSO_4.5H_2O + H_2S = 5H_2O + H_2SO_4 + CuS.$$

16. 1000 gm. of copper are dissolved in hydrogen sulphate. How much blue vitriol and what volume of sulphur dioxide at 13° C. is formed?

$$Cu + 2H_2SO_4 + 3H_2O = CuSO_45H_2O + SO_2.$$

17. What volume of hydrogen sulphate (Δ 1·84) and mass of copper are required to give 30 L. of sulphur dioxide?

$$Cu + 2H_2SO_4 = CuSO_4 + 2H_2O + SO_2.$$

18. A current of electricity is passed through acidulated water and copper sulphate. While 246 ccm. of hydrogen measured over water at 15° C. and 750 mm. are evolved, how much copper precipitates?

$$H_2O = H_2 + O.$$
$$CuSO_4 + H_2O = Cu + H_2SO_4 + O.$$

19. 0·5965 gm. of copper sulphate gave 0·2983 gm. of cuprous sulphocyanide. What is the percentage of copper in the sulphate?

$$2CuSO_45H_2O + 2KCNS = 2HKSO_4 + 9H_2O + O + Cu_2C_2N_2S_2.$$

20. Find the percentage of water in each of the cupric sulphates: —(α) $CuSO_4.H_2O$, (β) $CuSO_4.2H_2O$, (γ) $CuSO_4.5H_2O$, (δ) $CuSO_46H_2O$, (ε) $CuSO_47H_2O$.

21. What volume of nitric oxide at 149° C. and 980 mm. is obtained on dissolving 4·9 gm. of copper in hydrogen nitrate?

$$3Cu + 8HNO_3 = 3Cu2NO_3 + 4H_2O + 2NO.$$

22. How much cupric oxide is formed on heating 1748 gm. of cupric nitrate?

$$Cu2NO_36H_2O = 6H_2O + 2NO_2 + O + CuO.$$

23. Find the formula of a substance containing copper 57·5, carbon 5·4, hydrogen 0·9, and oxygen 36·2 per cent.

24. What volume of carbon dioxide at 17° C. and 720 mm. is given off on dissolving 137 gm. of azurite in hydrogen nitrate?

$$CuH_2O_22CuCO_3 + 6HNO_3 = 3Cu2NO_3 + 4H_2O + 2CO_2.$$

25. What volume of hydrogen at 100° C. and 746 mm. is given off on dissolving 3 gm. of cuprous hydride in hydrogen chloride?

$$Cu_2H_2 + 2HCl = Cu_2Cl_2 + 2H_2.$$

26. 2 gm. of cuprous hydride, when dissolved in hydrogen chloride, gave 723 ccm. of hydrogen at 12° C. What is the atomic weight of copper?

$$Cu_2H_2 + 2HCl = Cu_2Cl_2 + 2H_2.$$

CHAPTER XXXVIII.

MERCURY, Hg = 200.

1. 8000 gm. of cinnabar are roasted. How much mercury and what volume of sulphur dioxide at 13° C. is formed?

$$HgS + O_2 = Hg + SO_2.$$

2. Mercury vapour is 6·976 times as heavy as air. Find its double density referred to hydrogen.

3. On heating 2·7 gm. of mercuric oxide, 195 ccm. of oxygen at 37° C. and 620 mm. were collected. What is the atomic weight of mercury?

4. A kilo. of mercury at 100° C. was mixed with a kilo. of water at 10° C. The temperature of the mixture was found to be 13° C. What is the specific heat of mercury?

5. 2 gm. of sodium amalgam, when placed in water, gave 623·6 ccm. of hydrogen at 3° C. and 480 mm. What percentage of sodium was there in the amalgam?

$$Na + H_2O = HNaO + H.$$

6. Find the formula of cadmium amalgam which contains mercury 78·26 and cadmium 21·74 per cent.

7. 10 ccm. of mercury (Δ 13·56) are thrown into a vacuous iron bottle, of 2 l. capacity, kept at 427° C. What is the internal pressure in atmospheres?

8. Find the formula of a substance containing mercury 77·52, carbon 18·6, and hydrogen 3·88 per cent.

9. 70 gm. of mercuric oxide are heated. What volume of oxygen at 21° C. and 740 mm. is given off?

$$HgO = Hg + O.$$

10. Excess of mercury is heated in 10 l. of air at 14° C. How much mercuric oxide is formed?

$$Hg + O = HgO.$$

11. What volume of mercury (Δ 13·5) and mass of mercuric chloride must be sublimed together to form 3 kilo. of mercurous chloride?

$$HgCl_2 + Hg = Hg_2Cl_2.$$

12. The vapour of mercurous chloride is 8·21 times as heavy as air. What is its apparent molecular weight?

13. 500 gm. of mercury are heated with excess of hydrogen sulphate. How much sodium chloride must be mixed with the mercuric sulphate, and how much mercuric chloride is formed?

$$HgSO_4 + 2NaCl = Na_2SO_4 + HgCl_2.$$

14. Find the formula of a substance containing mercury 50·5, chlorine 35·86, nitrogen 7·07, hydrogen 2·02, and water 4·55 per cent.

15. How many grams do 500 ccm. of the vapour of mercuric chloride ($HgCl_2$) at 350° C. weigh?

16. What volume of hydrogen sulphide at 12° C. and 780 mm. is required to throw down the mercury from 126 gm. of mercuric cyanide?

$$HgC_2N_2 + H_2S = HgS + 2HCN.$$

17. 100 ccm. of mercury (Δ 13·56) are warmed with hydrogen nitrate. What volume of nitric oxide at 26° C. is evolved?

$$3Hg + 8HNO_3 = 3Hg2NO_3 + 4H_2O + 2NO.$$

18. Find the percentage composition of mercuric hydronitrate ($HgHNO_4$).

19. What is the percentage composition of turpeth mineral ($HgSO_42HgO$)?

20. 40 gm. of mercury are evaporated with 50 gm. of hydrogen sulphate. How much mercuric sulphate and what volume of sulphur dioxide at 39° C. are formed?

$$Hg + 2H_2SO_4 = HgSO_4 + 2H_2O + SO_2.$$

21. According to Erdmann and Marchand 177·1664 gm. of mercuric sulphide when heated with copper give 152·745 gm. of mercury. What is the atomic weight of mercury?

$$HgS + Cu = CuS + Hg.$$

22. How much potassium iodide must be poured into a solution of 379 gm. of mercuric chloride, and how much mercuric iodide is formed?

$$HgCl_2 + 2KI = 2KCl + HgI_2.$$

CHAPTER XXXIX.

SILVER, Ag = 108.

1. Calculate the percentage composition of (α) horn-silver AgCl, (β) silver glance Ag_2S.

2. Find the symbol of Proustite which contains silver 65·45, sulphur 19·39, and arsenic 15·16 per cent.

3. How much (α) iron, (β) mercury is required to reduce 48 lb. of silver chloride?

$$2AgCl + Fe = FeCl_2 + 2Ag.$$
$$2AgCl + 2Hg = Hg_2Cl_2 + 2Ag,$$

4. How many litres of air (containing 20 per cent. by volume of available oxygen) are required to cupel a ton of lead containing 320 oz. troy of silver?

$$Pb + O = PbO.$$

5. Melted silver dissolves 22 times its volume of oxygen at 0° C. What volume of oxygen at 13° C. would be given off by a kilogram of silver (Δ 10·5) on cooling?

6. A kilogram of silver (Δ 10·512) was found when cold to occlude 174 ccm. of oxygen. Find the percentage of oxygen by mass and by volume.

7. 105·3 ccm. of hydrogen precipitate 1·01 gm. of silver from a solution of silver acetate. What is the atomic weight of silver?

$$AgC_2H_3O_2 + H = HC_2H_3O_2 + Ag.$$

8. A shilling weighs 87·27 grains, of which 80·727 are silver. How many shillings can be made from a ton of silver, and how many tons do they weigh?

9. According to Levol an alloy of 71·9 silver, and 28·1 copper per cent. does not separate on cooling. Find the formula of it.

10. When mercury was placed in a solution of silver a crystalline amalgam containing 26·45 per cent. of silver separated. Find a formula for the amalgam.

11. What volume of oxygen at 30° C. can be obtained on heating 10 gm. of silver oxide?

$$Ag_2O = Ag_2 + O.$$

12. 10 gm. of silver oxide are exposed to sunshine. What volume of oxygen measured over water at 15° C. and 740 mm. is evolved if

(α) silver, (β) silver suboxide is formed? The water stands at 217 mm. in the tube.

$$2Ag_2O = 2Ag_2 + O_2.$$
$$2Ag_2O = Ag_4O + O.$$

13. What volume of oxygen at 39° C. is evolved on throwing 4 gm. of silver oxide into hydrogen dioxide?

$$Ag_2O + H_2O_2 = Ag_2 + H_2O + O_2.$$

14. What volume of oxygen at 21° C. and 740 mm. is evolved when one gram of silver dioxide is (α) heated, (β) thrown into hydrogen dioxide?

$$Ag_2O_2 = Ag_2 + O_2.$$
$$Ag_2O_2 + 2H_2O_2 = Ag_2 + 2H_2O + 2O_2.$$

15. Find the percentage composition of silver oxyfluoride (Ag_2HFO).

16. According to Stas 53·1958 gm. of silver form 92·6042 gm. of silver bromide (AgBr). What is the atomic weight of silver?

17. A gram of silver chloride (AgCl) when reduced by hydrogen left 0·7526 gm. of silver. Find the atomic weight of silver.

18. How much sodium carbonate is required to reduce 500 gm. of silver chloride?

$$2AgCl + Na_2CO_3 = 2NaCl + CO_2 + O + Ag_2.$$

19. How much sodium chloride must be dissolved in a litre of water that 1 ccm. of the solution may precipitate 0·01 gm. of silver?

$$AgNO_3 + NaCl = AgCl + NaNO_3.$$

20. 100 gm. of silver chloride absorb 17 gm. of ammonia. Find a formula for the compound, and calculate from the formula how much chloride is united with 17 gm. of ammonia.

21. How much silver sulphide is formed on heating 67·2 gm. of silver in the vapour of sulphur?

$$Ag_2 + S = Ag_2S.$$

22. What volume of hydrogen sulphide at 27° C. and 570 mm. is required to precipitate the silver from 100 gm. of silver metaphosphate?

$$2AgPO_3 + H_2S = Ag_2S + 2HPO_3.$$

23. 487 gm. of silver are heated with hydrogen sulphate. How much silver sulphate and what volume of sulphur dioxide at 26° C. and 780 mm. are formed?

$$2Ag + 2H_2SO_4 = Ag_2SO_4 + 2H_2O + SO_2.$$

24. 480 gm. of silver are dissolved in hydrogen nitrate. How much silver nitrate and what volume of nitric oxide at 17° C. are formed?

$$6Ag + 8HNO_3 = 6AgNO_3 + 4H_2O + 2NO.$$

CHAPTER XL.

GOLD, Au = 196·6.

1. A sovereign weighs 123·274 grains, of which 113·001 are gold. How many sovereigns can be made from a ton of gold, and how many tons do they weigh?

2. Find a formula for mint-gold, which consists of 11 pts. of gold to 1 part of copper. And find the percentage of gold in a body having that formula.

3. How much ferrous sulphate is required to precipitate 100 gm. of gold?

$$6FeSO_4 7H_2O + 2AuCl_3 = 4Fe_2 3SO_4 + 42H_2O + Fe_2Cl_6 + Au_2.$$

4. According to Levol 1000 pts. of gold when converted into the chloride and exposed to the action of sulphur dioxide form hydrogen sulphate sufficient to give 1782 pts. of barium sulphate. Find the atomic weight of gold.

$$2AuCl_3 + 3SO_2 + 6H_2O = 2Au + 6HCl + 3H_2SO_4.$$
$$3H_2SO_4 + 3BaCl_2 = 6HCl + 3BaSO_4.$$

5. How much magnesia is required to throw down 10 gm. of auric oxide?

$$2AuCl_3 + 3MgO = 3MgCl_2 + Au_2O_3.$$

6. What volume of oxygen is given off on heating 4·412 gm. of auric oxide?

$$Au_2O_3 = 2Au + 3O.$$

7. What volume of oxygen at 12° C. is evolved on throwing 0·2 gm. of auric oxide into hydrogen dioxide?

$$Au_2O_3 + 3H_2O_2 = Au_2 + 3H_2O + 3O_2.$$

8. Prat has described an oxide of gold containing 7·7 per cent. of oxygen. Find its formula.

9. Find the formula of a substance containing gold 77·22, oxygen 9·42, nitrogen 11, and hydrogen 2·35 per cent.

10. Purple of Cassius, prepared by Pelletier's method, is found to contain stannic oxide 32·746, stannous oxide 14·618, aurous oxide 44·772, and water 7·864 per cent. Find a formula for it.

11. How much aurous bromide can be made from 2 gm. of aurous oxide?

$$Au_2O + 2HBr = H_2O + 2AuBr.$$

12. How much auric chloride can be made from 20 gm. of gold?

$$Au + 3Cl = AuCl_3.$$

13. Find the percentage composition of ammonium chloraurate ($NH_4AuCl_4H_2O$).

14. How much iron can be converted from a ferrous to a ferric salt by 10 gm. of auric chloride?

$$6FeCl_2 + 2AuCl_3 = 3Fe_2Cl_6 + 2Au.$$

15. 50 gm. of auric chloride are heated to 170° C. How much aurous chloride and what volume of chlorine at 21° C. are formed?

$$AuCl_3 = AuCl + Cl_2.$$

16. A solution of 10 gm. of auric chloride is mixed with hydrogen oxalate. How much gold precipitates, and what volume of carbon dioxide at 13° C. is given off?

$$2AuCl_3 + 3C_2H_2O_4 = 2Au + 6HCl + 6CO_2.$$

PLATINUM, Pt = 195.

17. How much spongy platinum is left on heating 100 gm. of ammonium chloroplatinate $(NH_4)_2PtCl_6$?

18. How much platinum black is obtained on boiling 40 gm. of platinic chloride with grape-sugar and sodium carbonate?

$$PtCl_4 + 2Na_2CO_3 = 4NaCl + 2CO_2 + O_2 + Pt.$$

19. 100 gm. of platinum black unite directly with 73·5 gm. of arsenic. Find a formula for the alloy, and calculate how much arsenic is required by the formula.

20. How much platinum tetrachloride is obtained on dissolving 500 gm. of platinum in aqua regia?

$$Pt + 4Cl = PtCl_4.$$

21. What volume of chlorine at 26° C. is evolved on heating 5·615 gm. of platinic chloride?

$$PtCl_4 = Pt + Cl_4.$$

22. 48 gm. of platinum tetrachloride are heated to 200° C. How much platinum dichloride and what volume of chlorine at 14° C. are formed?

$$PtCl_4 = PtCl_2 + Cl_2.$$

23. How much platinous hydrate is formed on digesting 200 gm. of platinous chloride with potassium hydrate?

$$PtCl_2 + 2HKO = 2KCl + PtH_2O_2.$$

24. How much platinous chloride must be heated to give a litre of chlorine at 35° C?

$$PtCl_2 = Pt + Cl_2.$$

25. Find the percentage composition of potassium chloroplatinate (K_2PtCl_6).

26. According to Berzelius 10 gm. of platinum form 24·735 gm. of potassium chloroplatinate. Find the atomic weight of platinum.

$$PtCl_4 + 2KCl = K_2PtCl_6.$$

27. Seubert, by heating platinum tetrachloride in hydrogen and precipitating the hydrogen chloride with silver nitrate, found 5·9242 gm. of platinum were left when 17·4139 gm. of silver chloride were formed. What is the atomic weight of platinum?

$$PtCl_4 + 4H = Pt + 4HCl.$$
$$4HCl + 4AgNO_3 = 4HNO_3 + 4AgCl.$$

28. Find the percentage composition of the green salt of Magnus ($N_2H_6PtCl_2$).

29. Find the formula of a substance containing nitrogen 13·83, hydrogen 2·96, platinum 48·13, and chlorine 35·07 per cent.

ANSWERS.

CHAPTER I.

An approximate answer is signified by ?

English and Metric Measures.

1. 78·54 scm.
2. 3000 l.
3. 35·343 cubic feet.
4. 2·68 lbs. troy ?
5. 344·42 m.
6. 148,055,600 kilom. ?
7. 299,330 kilom. ?
8. 1,170,560 cub. ft.
9. 1178·1 l.
10. 1·855 m.
11. 92,000,000 miles ?
12. 96,051,852 cub. feet.

Volume Mass and Density.

13. Δ 7·8.
14. Δ 0·8504.
15. Δ 0·579.
16. 1428·57 gm.
17. 5250 kilo.
18. 974·659 cm. ?
19. 22776·6 kilo.
20. 1 l.
21. Δ 1·2.
22. 1400 kilo.
23. 3848 gm.
24. 159·44 tons.
25. 52,364,199 tonnes.
26. Δ 7·4.
27. Δ 1·843.
28. 5·47723 gm.
29. Δ 2·63.
30. Turpentine Δ 0·909. Copper sulphate Δ 2·295.
31. 2·764.
32. 2·604.
33. 2·689.
34. 2·163.
35. 1·163.

CHAPTER II.

Molecular Weights.

1. (i.) 28. (ii.) 40·4. (iii.) 56. (iv.) 60·4. (v.) 102.
2. (i.) 57·14 %. (ii.) 39·6 %. (iii.) 28·57 %. (iv.) 53 %. (v.) 47·06 %.
3. (i.) 30. (ii.) 40. (iii.) 160. (iv.) 100. (v.) 128.

4. (i.) 320.
(ii.) 463.
(iii.) 233.
(iv.) 331.
(v.) 212.

5. (i.) 287·4
(ii.) 249·3.
(iii.) 322.
(iv.) 280.
(v.) 223.

6. (i.) 46.
(ii.) 74.
(iii.) 60.
(iv.) 126.
(v.) 150.

7. (i.) 92.
(ii.) 136.
(iii.) 93.
(iv.) 284.
(v.) 342.

8. (i.) 122·5.
(ii.) 382.
(iii.) 355·6.
(iv.) 197.
(v.) 294.

9. (i.) 422.
(ii.) 182·4
(iii.) 248.
(iv.) 209.
(v.) 596.

10. (i.) Mercury 92·59 %.
Oxygen 7·41 %.

(ii.) Potassium 31·83 %.
Chlorine 28·98 %.
Oxygen 39·18 %.

(iii.) Manganese 63·2 %.
Oxygen 37·8 %.

11. Copper 25·39 %.
Sulphur 12·84 %.
Oxygen 25·67 %.
Water 36·1 %.

12. Carbon 49·5 %.
Hydrogen 5·15 %.
Nitrogen 28·86 %.
Oxygen 16·49 %.

CHAPTER III.

TEMPERATURES.

1. (i.) 45° C.
(ii.) 35° C.
(iii.) 95° C.
(iv.) 75° C.
(v.) 65° C.

2. (i.) 72° R.
(ii.) 12° R.
(iii.) 16° R.
(iv.) 44° R.
(v.) 24° R.

3. (i.) 158° F.
(ii.) 168° F.
(iii.) 126° F.
(iv.) 17° F.
(v.) − 25° F.

4. (i.) 7·1° R.
(ii.) 43·1° R.
(iii.) 60·4° R.
(iv.) 79·1° R.
(v.) −27·56° R.

5. (i.) 140·9° F.
(ii.) 104° F.
(iii.) 158° F.
(iv.) 23° F.
(v.) − 33·97° F.

6. (i.) 97·2° C.
(ii.) 82·2° C.
(iii.) 45·56° C.
(iv.) − 17·8° C.
(v.) − 34·4° C.

7. (i.) 1189·4° F.
(ii.) 1328° F.
(iii.) 1580° F.
(iv.) 1783·4° F.
(v.) 1832° F.

8. (i.) 356·7° C.
(ii.) 37·78° C.
(iii.) 239·4° C.
(iv.) 1914·4° C.
(v.) 1616·1° C.

9. (i.) 279°.
(ii.) 353°.
(iii.) 233°.
(iv.) 259°.
(v.) 178°.

10. (i.) 294·1°.
(ii.) 253°.
(iii.) 313°.
(iv.) 1366·3°.
(v.) 234·67°.

11. (i.) 27° C. 21·6° R. 80·6° F.
(ii.) 127° C. 101·6° R. 260·6° F.
(iii.) 227° C. 181·6° R. 440·6° F.

12. 42° F. = 5·5° C. = 4·4° R.
− 32° F. = − 35·5° C. = − 28·4° R.
327° R. = 408·75° C. = 767·75° F.

13. − 459·4° F.

− 2° R. = − 2·5° C. = 27·5° F.
78° C. = 62·4° R. = 172·4° F.

14. − 40° C. or F.

− 172° C. = − 137·6° R. = − 277·6° F.

Pressures.

15. 0·703 kilo.
16. 813·6 cm.
17. 5·6096 m.
18. 787·4 mm.
19. 29·724 inches.
20. (α) 33·37 ft.
(β) 14·46 lbs.

CHAPTER IV.

The Volume of a Mass of Gas.

1. 1142·85 ccm.
2. 1388·8 ccm.
3. 826·59 ccm.
4. 82·644 ccm.
5. 403·94 ccm. ?
6. 397·52 l.
7. 1181·81 ccm.
8. 258·14 ccm.
9. 100·03 l.
10. 1097·56 ccm.
11. 791·6 ccm.
12. 183·63 l.
13. 52·47 ccm.
14. 140·25° C.
15. 1500 ccm.
16. 300 ccm.
17. 147·49 ccm.
18. 760 ccm.
19. 300 ccm.
20. 1111 ccm.
21. 1000 ccm.
22. 651·058 ccm. ?
23. 1333·3 ccm.
24. 213·02 l.
25. 1096·509 ccm.
26. 105·627 ccm.
27. 349·14 ccm.
28. 9541·9 ? ccm.
29. 265·8° C.
30. 900·28 mm.
31. 3668° C.
32. 1230·47 ccm.
33. 1000 ccm.
34. 209·05 l. ?
35. 894·96 ccm.
36. 59·92 ccm.
37. 1895·604 ccm.
38. 10 ccm.
39. 29·5 inches.
40. 976·95 ccm.
41. 186·26 ccm.
42. 534 grains ?

CHAPTER V.

OXYGEN.

Answers followed by ! *are obtained by using* 22·32 *litres as two volumes, and* ·00367 *as the coefficient of expansion of a gas.*
! *after an answer means nearly.*

1. Mercury 9·259 gm.
   Oxygen 0·74 gm.
2. 64 gm.
3. 19·59 gm.
4. (α) 1350 gm.
   (β) 255·2 gm.
   (γ) 815·6 gm.
5. 14 l.
6. (α) 1·716 l.
   (β) 2·574 l.
7. 27·43 l.
8. 5·185 l.
9. 28·6 gm. ?
10. 0·27 gm.
11. 408·3 gm.
12. 116·518 gm
13. 255·2 gm.
14. 14·93 l.
15. 490 gm. chlorate.
    192 gm. oxygen.
16. 33·66 l.
17. 9·876 kilo.
18. 4·718 kilo.
19. 8·29 l.
20. 14 l. normal.
    16·146 l.
21. 17·78 gm. oxygen.
    145·018 gm. dioxide.
22. 120·565 l.
23. 590·77 l.
24. 77·64 gm.
25. 22·87 gm.
26. 32·169 l. ?
27. 92·7 ccm.
28. 1·177 l.
29. 253·9 ccm.
30. 269·88 ccm.
31. O = 15·959 ?
32. 150·1 ccm.
33. 0·716 gm. !
34. 1·222 l. !
35. (α) 13·8 l. !
    (β) 12·25 l.

CHAPTER VI.

HYDROGEN.

1. 14·28 ccm. – 397·3° F.
2. 34·25 l.
3. (α) 2·2 kilo. zinc.
   (β) 3·281 kilo. acid.
4. 14·69 l. ?
5. 4·017 gm.
6. 5·714 kilo.
7. 49·39 gm.
8. 132·1 l.
9. 0·10174 gm.
10. 2·857 gm.

11. 42·196 l.
12. 333·18 ccm.
13. 13·94 l. ?
14. 2·546 l.
15. 422·8 kilo. zinc.
633·3 kilo. sulphate.
16. 700·7 gm.
17. ·005593 lb. hydrogen.
·080728 lb. air.
18. 2928 lbs. hydrogen.
42,269 lbs. air.
19. 75·14 lbs. !
20. 199·8 ccm.
21. 230·1 gm. !
22. 13·52 kilo. !
23. (α) 29·8 ccm. !
(β) 191·3 ccm. !
(γ) 15·26 ccm. !
24. 0·06955 gm. !
25. 26·95 l. !

CHAPTER VII.

WATER.

1. 88·8646 % oxygen.
11·1345 % hydrogen.
2. 12·4 l. hydrogen.
6·2 l. oxygen.
3. 261·2 l.
4. (α) 974·66 ccm. ?
(β) 1087 ccm. ?
5. 3·964 × 10^{10} kilo.
6. 34·9 cub. ft. ?
7. 304·3 l.
8. 1087 ccm. ?
9. 287,944 cub. m.
10. 12·1 kilo.
11. 6·6 ccm.
12. 54·67 l. ?
13. (i.) 62·937 gm.
(ii.) 57·6 gm.
(iii.) 45·92 gm.
(iv.) 14·52 gm.
14. 8.
15. 12·5.
16. 88·897 % oxygen.
11·102 % hydrogen.
17. 136·2 l.
18. 6·7132 l.
19. 648 ccm. ?
20. nil.
21. 0·494 gm.
22. 23781·2 gm at 27·15° C.
23. 10·73 gm.
24. 2612 times.
25. 0·296.
26. 33·81 cub. feet.
27. 202·3 ccm. ?
28. 479·3 times ?
29. 4·17 % dioxide.
95·83 % water.
30. 258·45 grains !
31. 3·402 l. !
32. 14·4 % !
33. 62·4156 lb.

CHAPTER VIII.

NITROGEN.

1. 125 gm.
2. 209·048 ccm.
3. 3·5 l.
4. 40·96 l.
5. N = 87·1.
6. 23·33 ccm.
   0·02916 gm.
7. 0·3279 gm.?
8. 1·12 l. dioxide.
   2·24 l. nitrogen.

HYDROGEN NITRATE.

9. 296·4 lbs.
10. 6·6 l.
11. 1142·9 gm.
12. 626·6 ccm. sulphate.
    494·1 ccm. nitrate.
13. 741·17 gm.
14. 242·57. gm.
15. 2436·8 gm. nitrate.
    1283·6 ccm. sulphate.
16. $4HNO_3.11H_2O$.
17. $2HNO_3.3H_2O$.
18. 691·56 ccm.
19. 900 gm.
20. 341·46 gm.
21. 3·57 kilo. ?
22. 55·52 oz.
23. 1·223 gm.
24. 7·518 l.
25. 2462 gm. ?
26. 76·7 ccm. nitrate.
    131·48 gm. pentoxide.

THE OXIDES OF NITROGEN.

27. 5 % hydrogen.
    35 % nitrogen.
    60 % oxygen.
28. 67·2 l.
29. 142·85 gm.
30. (α) 196·43 gm.
    (β) 133·93 gm.
31. 9·1 l.
32. 5·09 l.
33. 2·106 gm.
34. 9·706 l.
35. 42·38 gm.
36. 6·18 l. ?
37. 23·938 l.
38. 17·7 l.
39. 5·448 l. ?
40. 10·472 l.
41. 2·41 l.
42. 5·6 l.
43. 55·47 l.
44. 11·089 l. nitrogen.
    16·633 l. dioxide.

45. 76·51 at 27° C.
45·3 at 180° C.

46.

	(α)	(β)
Nitrogen	21·37	17·17 %
Oxygen	24·43	39·26 %
Chlorine	54·2	43·55 %

47. 1·39 l.

48. 100·01 ccm.

Ammonia.

49. 680 gm.
50. 13·176 l.
51. 131·77 l.
52. 191·07 gm.
53. 28·64 l.
54. 97·08 l.
55. 1·7 gm.
56. 1·76 kilo.
57. 6·137 l.
58. 14·5 ccm. nitrogen.
8·25 ccm. oxygen.
59. 163 ccm. ?
60. 2·82 gm.
606 ccm.
61. 14·84 % !
62. AgNO. ?
63. Nitrogen 2·59 %.
Mercury 73·94 %.
Iodine 23·47 %.
64. 10·35 l. !
65. 9·175 gm. !
66. 177·5 ccm. !

67.

	(α)	(β)
Nitrogen	87·5	97·674.
Hydrogen	12·5	2·326.

68. Na_3N. sodium imide.

CHAPTER IX.

The Atmosphere.

1. 20·72 % oxygen by vol.
23 % oxygen by mass.
2. 30 gm.
3. 15·8 ccm. nitrogen.
21·6 ccm. hydrogen.
4. 20 95 % oxygen.
5. 0·2325 gm.
6. 19·09 l. air.
4·44 gm. ?
7. 21·46 gm. ?
8. 93 l. nitrogen.
40 ccm. ammonia.
9. 80° C. ?
10. 560 l.
11. 0·54 gm. more nitrogen.
12. 25·88 gm.
13. 8·1 lb.
14. 78·15 tons ?
15. 600·32 kilo.
16. 0·2584 gm.
17. 757·29 lbs. air.
176·446 lbs. oxygen.
18. 89·7 kilo.
19. 54 kilom. radius.
20. 101·12 tons.
21. 1554×10^6 steres.
22. 149·3 ccm.
23. 20·56 % oxygen.
24. 668·1 gm.

25. 5·478 gm.
26. 90·74 lit.
27. 2·068 gm.
28. 133·7 ccm. !
29. 103,100 tons ?
30. 197 tons ?
31. Oxygen 19·37 %.
Nitrogen 79 %.
Carbon dioxide 1·629 %.
32. 18·6° C. 70·4 gm.
33. 591 mm. ?
2160 m. high ?
34. $5·75 \times 10^{11}$ tonnes carbon.
35. 0·82 %.
36. 0·1783 gm.

CHAPTER X.

CARBON.

1. 6·1 ccm. ?
21·7 ccm.
2. 1111·1.
3. Gr = 32·3.
4. 99·84 lbs.
5. 0·978 ton ?
6. 500·5 m.

CARBON MONOXIDE.

7. 33·6 l.
8. 4·756 l. dioxide.
2·547 gm. carbon.
9. 126·65 gm.
10. 524·1 gm.
11. 1·317 l.
12. (α) 80 l.
(β) 50·9 l.
13. 11·513 gm.
14. 20 ccm. oxygen.
15. 20 ccm. monoxide.
35 ccm. oxygen.
16. COS.

CARBON DIOXIDE.

17. 13·06 l. ?
18. 9·739 l.
19. 15·63 l. ?
20. 31·2 lbs. dioxide.
13·4 lbs. water.
21. 2·37 l. ?
22. 21·1 gm.
23. 43·105 gm.
24. 81·558 gm.
25. 2·506 oz. carbonate.
4·477 oz. tartrate.
26. 8888·8̇ l.
27. 0·535 gm.
28. − 83·7° C.
29. 1·301 l.
30. Potassium 60 %.
Carbon 18·46 %.
Nitrogen 21·54 %.

Marsh Gas. Ethene. Acetylene.

31. 48·75 gm.
32. (α) 1·16 gm.
(β) 1·25 gm.
33. 59·96 gm.
34. 3·4125 gm.
35. 45·05 l.
36. 50 ccm. dioxide.
25 ccm. oxygen.
37. 100 ccm.
38. 281·3 ccm. ?
39. 20 l. !
40. 379·95 gm.
41. 3·768 l. !
1·633 ccm.
42. 1·536 cm.
0·01302 gm. !

Vapour Densities.

43. 1·134 gm. !
44. 22·5 !
45. 42·9 !
46. 21·58 !
47. 110·9 !
48. 102·1 !

Percentage Composition and Formula.

49. CH_2O.
50. $C_2O_3H_2O$ hyd. oxalate.
51. $C_6H_{14}O_6$ mannite.
52. C_5H_7N.
53. $C_2H_6SO_4$ ethyl hyd. sulph.
54. $C_7H_{10}O_4$ methyl citraconate.
55. $C_{13}H_{20}N_4O_5$ gelatin.
56. $C_8H_{10}N_4O_2$ theine.
57. $C_5H_4N_4O_3$ hyd. urate.
58. $C_7H_6O_2$ hyd. benzoate.
59. C_6H_{12}.
60. C_7H_8O.
61. $C_7H_6O_2$ hyd. benzoate.
62. $C_{27}H_{24}N_4$.
63. Carbon 39·08 %.
Hydrogen 2·18 %.
Nitrogen 15·23 %.
Oxygen 43·51 %.
$C_6H_4N_2O_5$.
64. Carbon 34·03 %.
Hydrogen 6·19 %.
Iodine 59·87 %.
Iodohexane $C_6H_{13}I$.
65. 47 ?
66. 130 ?
67. 174 ?
68. 4620 ?
69. 153 ?
70. 122 ?
71. 252 ?
72. 129 ?
73. 126 ?
74. 123 ?
75. 63 ?
76. 60·4 ?

CHAPTER XI.

Chlorine.

1. 56 l.
2. 122·53 gm.
3. 397·83 l.
4. 146·25 gm.
5. 136·81 gm.
6. 39·938 ccm.
7. 315·5 ccm. ?
8. 2·726 ccm. hydrogen.

Hydrogen Chloride.

9. 179·2 l.
10. 1603 gm. ?
11. 0·391 gm.
12. 75·72 lb.
13. 32·4 kilo. salt.
14. 47·87 l. ?
15. 5·761 % real acid.
16. 99·31 kilo.
17. 780·5 ccm. ?
18. (α) 1·74 gm. pp.
    (β) 1·913 gm. left.

The Oxygen Compounds of Chlorine.

19. 8·69 l. chlorine.
    4·148 l. monoxide.
20. 201·57 l.
21. 743·1 l.
22.

	(α)	(β)	(γ)
Calcium	27·97	31·5	32·97
Oxygen	22·38	12·6	26·37
Chlorine	49·65	55·9	39·01
Hydrogen			1·65

23. 59·5 for Cl_2O_3.
    67·5 for Cl_2O_4.
24. 22·4 l. oxygen.
    138·5 gm. perchlorate.
25. 124·4 gm. ?
26. $KClO_4$.
27. 236 l. !
28. 2·596 l. !
29. 6·28 ccm. chlorine !
30. 3·784 l. !
31. 4·444 l. !
32. 102·3 ccm. !
33. 1·841 l.
34. 93·4 % !
35. 50·56 % !
36. 64·8 % ?
37. 3·088 gm. !
38. 6·22 gm. !
39. 15·12 l. !
40. 16·35 gm. !

CHAPTER XII.

Bromine.

1. 49·39 tonnes ?
2. 14·875 gm.
3. 151·2 ccm.
4. 47·06 % bromine.
    52·94 % water.
5. 220 ccm.
6. 1·855 l.
7. 10·338 l.
8. 4·613 gm. phosphorus.
    11·9048 ccm. bromine.
9. 20·81 gm.
10. 3·57 gm.
11. 0·4592 gm.
12. 80·84 !
13. 748·1 gm.
14. Br. = 80·135. ?
15. 57·44 % silver.
    42·55 % bromine.
16. (α) 644·6 gm. bromide.
    (β) 180·9 gm. bromate.
17. 2·107 l.
18. 9·266 mm.

CHAPTER XIII.

IODINE.

1. 520·76 kilo.
2. 43·67 gm.
3. 83 gm.
4. 17·52 gm. ?
5. 0·2592 gm.
6. 251·6.
7. 994 times.
8. 672 ccm.
9. 19·84 gm. iodine.
   1·75 l. sulphide.
10. 1·86 l.
11. 38·4 gm. iodine ?
    1·9 gm. phosphorus ?
    20 gm. iodide ?

12.

	α	β	γ	δ
Hydrogen			0·57	0·52 %.
Iodine	76·05	69·4	72·2	66·14 %.
Oxygen	23·95	30·6	27·23	33·34 %

13. (α) and (β) 0·04464 gm.
14. 877·09 gm.
15. 52·47 l.
16. 721·5 gm. iodine.
    580 gm. chlorate.
17. 2·303 l. ?
18. 1·069 l.
19. 40·62 gm. phosphorus !
    499·1 gm. iodine !
20. 54·4 gm. !
21. Carbon 3·046 %.
    Hydrogen 0·254 %.
    Iodine 96·7 %.
22. Iodine 2·378 gm.
    Bromine 2·978 gm.
    Chlorine 1·032 gm.

CHAPTER XIV.

FLUORINE.

1. α
   Calcium 51·28 %.
   Fluorine 48·72 %.

   β
   Aluminium 12·85 %.
   Sodium 32·85 %.
   Fluorine 54·3 %.
2. 174·36 gm. sulphate.
   51·28 gm. fluoride.
3. 0·5835 gm.
4. 30·47 l.
5. 13·73 l.
6. 259·55 ccm. ?
7. 0·281 gm.
8. 19·002.
9. 60·4 gm. silica.
   288·8 gm. fluosilicate.
10. 151·48 ccm. ?
11. 15·63 gm. !
12. 21·24 l. !
13. 19·6 !
14. Carbon 13·64 %.
    Fluorine 86·36 %.

CHAPTER XV.

SULPHUR.

1. Lead 86·6 %. Zin 67·15 %. 2. (α) $CuFeS_2$.
   Sulphur 13·4 %. Sulphur 32·85 %. (β) $CaSO_4$.
3. (α) 487·8 ccm.
   (β) 511 ccm.
4. 2513 gm.
5. 28·76 l.
6. S = 32·0004.
7. 3333·3 l. ?
8. 88·019 gm.

SULPHUR DIOXIDE.

9. 14 l.
10. 14·285 gm.
11. 3062·5 gm. sulphate.
    989·06 gm. copper.
12. 2·24 l.
13. 71·7 l.
14. 2·5194 l.
15. 26·51 gm.
16. 6·72 l.
17. 20 l.
18. 1·184 gm.
19. 64.
20. 2·828 ccm.
21. Sodium 18·54 %.
    Sulphur 25·81 %.
    Oxygen 19·36 %.
    Water 36·29 %.
22. 0·5121 gm. iodine ?
    0·5443 gm. tetrathionate.

HYDROGEN SULPHATE.

23. 313·6 gm.
24. 1·63 ton.
25. 4·57 cwt.
26. 887·68 l.
27. 459·375 kilo.
28. 108·84 tons.
29. 465·28 grains.
30. 600·8 gm.
31. 11,040 kilo.
32. 13·02 tonnes.
33. Hydrogen 0·79 %.
    Sulphur 25·20 %.
    Nitrogen 11·02 %.
    Oxygen 62·99 %.
34. $H_2S_2O_7$ Nordhausen acid.
35. 49.
36. 11·27 l. ?
37. 284·7 gm.
38. 200·26 ccm.
39. 100·14 tons colcothar.
    111·41 tons acid.
40. 13·63 gm.
41. 98·15.
42. 5·216 l.

Hydrogen Sulphide.

43. 15·54 l. ?
44. 2·54 l.
45. 392·85 gm.
46. 11·662 l.
47. 70·64 l.
48. 86·57 l.
49. 28·27 l.
50. 1·177 l
51. 0·857 gm.
52. 7·143 l.
53. 9·701 ccm.
54. 6·994 l. sulphur vap.
    9·326 l. steam.
55. 172·5 ccm.
56. 5·074 gm. lead sulphide.
    4·926 gm. mercury sulphide.

Carbon Disulphide.

57. 935 ccm.
58. 4·491 l.
59. 1·082 l. ?
60. 3·777 l. carbon dioxide.
    7·555 l. sulphur dioxide.
61. 26·3 gm.
62. 45·27 l. ?
63. 9·686 gm. !
64. 11·77 l. !
65. 612·2 kilo pyrites !
    2145 cub. m. air !
    478·5 cub. m. steam !
66. 1170 l. !
67. 12·54 ccm. !
68. 17·87 l !

CHAPTER XVI.

Boron.

1. Sodium 12·04 %.
   Boron 11·52 %.
   Oxygen 29·32 %.
   Water 47·12 %.
2. Boron 6·01 %.
   Chlorine 77·60 %.
   Nitrogen 7·65 %.
   Oxygen 8·74 %.
3. (α) B_2O_3.
   (β) SiO_2.
4. 117·5.
5. 0·7333 gm.
6. 441·6 l.
7. 4·726 l.
8. 6·57 l.
9. 6·13 l.
10. $H_6B_4O_9$ at 100° C.
    $H_2B_4O_7$ at 160° C.
11. 18·177 l.
12. 3·388 gm. !
13. 21·03 l. !
14. $3NH_3.2BCl_3$.

CHAPTER XVII.

SILICON.

1. 15·33 gm. ?
2. Barium 49·03 %.
   Silicon 10·17 %.
   Fluorine 40·8 %.
3. Zinc 58·6 %.
   Silicon 12·7 %.
   Oxygen 28·7 %.
4. 1·77 gm.
5. Si = 27·85.
6. Magnesium 19·22 %.
   Silicon 29·83 %.
   Oxygen 46·22 %.
   Water 4·73 %.
7. $CaMgSi_2O_6$.
8. 2·198 inches.
9. $CaSiO_3$.
10. $Al_2SiO_5.5H_2O$.
11. $Mg_2Si_2O_6.H_2O$.
12. 30·6 gm. sulphide.
    7·77 l. dioxide.
13. 0·654 gm.
14. 4·858 gm.
15. 3·88 l.
16. 5·443 l.
    19·2 gm.
17. 28·79 l.
    14·08 gm. carbon
18. 171·5 for $SiCl_4$.
    104 for SiF_4.
19. 4·39 gm.
20. 1·613 gm.
21. $FeMg_3Ca_4Si_8O_{24}$.
22. $(CaO)_2(Na_2O)(Al_2O_3)_3(SiO_2)_9(H_2O)_9$.
23. $(Al_2O_3)_3(SiO_2)_3F_2$.
24. $(Na_2O)(CaO)_3(Al_2O_3)_4(SiO_2)_9(H_2O)_{10}$.
25. $([FeMg]O)_4(Al_2O_3)_4(SiO_2)_{10}H_2O$.
26. $[K_2Na_2Ca]O[Al_2Fe_2]O_36SiO_2$.
27. Silicon 17·3 %.
    Oxygen 29·2 %.
    Carbon 43·8 %.
    Hydrogen 9·7 %.
28. 735 ccm. !
29. 3·667 gm. !
30. 1366·6 gm. ?

CHAPTER XVIII.

PHOSPHORUS.

1. 140 gm.
2. 20·4 kilo.
3. 2·784 lb.
4. Calcium 38·84 %.
   Carbon 1·16 %.
   Phosphorus 18·06 %.
   Oxygen 41·94 %.
5. 304·5 kilo.
6. 3167 kilo.?

7. 84·61 lb.
8. Carbon 12 lb.
   Silica 12·08 lb.
   Phosphorus 12·4 lb.
9. 15·65 kilo.
10. 57·49 gm.
11. 85·5 l.
12. 2·41 gm.
13. 127·6.
14. 1066·6 l.
15. 0·9582 gm. ?
16. 31·01 ?

Phosphorus Trioxide. Hydrogen Phosphite.

17. 25·92 gm.
18. 114·3 l.
19. (α) 682·9 ccm.
    (β) 1·7 l. ?
20. 42·58 gm. hypophosphite.
    3·61 l. phosphine.

Phosphorus Pentoxide. Hydrogen Phosphate.

21. 20·46 gm.
22. (α) 71·11 gm.
    (β) 47·4 gm.
    (γ) 23·7 gm.
23. $H_4P_2O_7$, or
    $H_{10}P_4O_{15}$, or
    $H_{24}P_{10}O_{37}$.
24. 5677·67 gm.
25. $Ca_3P_2O_8$.

26.		(α)	(β)	(γ)
	Silver	77·33	71·29	57·76 %
	Phosphorus	7·4	10·23	16·58 %
	Oxygen	15·27	18·48	25·66 %

27.		(α)	(β)
	Sodium	12·85	11·00 %
	Nitrogen	—	6·7 %
	Hydrogen	0·28	2·39 %
	Phosphorus	8·66	14·83 %
	Oxygen	17·87	30·62 %
	Water.	60·33	34·45 %

28. 8·03 l.
29. 24·5 gm.
30. 191·9 l. ?

Phosphine.

31. 5·395 l.
32. 2·051 l.
33. 952·8 ccm.
34. 4·929 l. ?
35. 1·119 l. ?
36. 1·3256 gm.
37. P_2H.
38. 34·2.
39. 1·705 l. air. ?
    0·567 gm. pentoxide.
40. 24·25 ccm.

The Halogen Compounds of Phosphorus.

41. 45·73 l. chlorine ?
58·25 ccm. oxychloride.
42. 201·44 gm.
43. $P_2O_3Cl_4$.
44. 153.
45. 3·265 gm.
46. 951·75 ccm.
47. 1163·2 l.
48. 17·54 l.
49. 137 ?
50. 954·36 l.
51. Sodium 29·36 %.
Phosphorus 26·38 %.
Oxygen 44·26 %.
52. $([MgFe]O)_6(P_2O_5)_5(Al_2O_3)_5(H_2O)_5$.
53. 5·309 gm. !
54. 9·17 l. !
55. 11·88 l. !
56. 4·553 l. !
57. 105·4 ?
58. 1·016 gm. !

CHAPTER XIX.

Arsenic.

1. 181·8 gm. carbon.
757·6 gm. arsenic ?
339·4 l. monoxide ?
2. 4·7084 gm.
3. 399·88 !
4. 26·79 gm. ?
5. Silver 65·45 %.
Arsenic 15·15 %.
Sulphur 19·4 %.
6. 124·24 gm. orpiment.
19·4 l. ?
7. 542 ccm.
8. 9·4412 grains.
9. Copper 33·8 %.
Hydrogen 0·53 %.
Arsenic 40·04 %.
Oxygen 25·63 %.
10. Potassium 40·62 %.
Arsenic 26·04 %.
Sulphur 33·33 %.

	α	β	γ
11. Arsenic	70·1	61	48·4 %
Sulphur	29·9	39	51·6 %

12. 156·1 grains.
13. 13·97 gm.
14. 36·55 l.
15. 8·42 l. nitrate.
14·34 kilo. arsenate.
1·185 cub. m. trioxide.
16. 354·5 gm. fluorspar.
242 ccm. sulphate ?
400 gm. trifluoride.
17. 90·909 gm. arsenic.
45·03 l. chlorine.
18. 0·2275 gm.
19. 238·7 ccm. ?
20. 3·482 gm.
21. Copper 24·99 %.
Arsenic 44·42 %.
Carbon 4·74 %.
Hydrogen 0·59 %.
Oxygen 25·26 %.
22. As = 74·91.
23. 8·29 gm. !
24. 733·5 ccm. !

CHAPTER XX.

ANTIMONY. BISMUTH.

1. 728·6 kilo. ?
2. 134 gm.
3. (α) 17·24 ccm.
   (β) 14·71 ccm.
   (γ) 10·1 ccm.
4. Δ 9·935.
5. Sb = 120·009.
6. Sb = 806·4516.
7. 29·3 l.
8. 0·6678 gm.
9. 49·57 l.
10. 9·007 l.
11. 94·79 gm.
12. 5·241 gm.
13. 72·83 % stibine
14. 507·2° F. 211·2° R.

	(α)	(β)	(γ)	(δ)
15. Bismuth	92·86	89·65	86·66	83·87
Oxygen	7·14	10·34	13·33	16·13

16. Bismuth 42·98 %.
    Nitrogen 8·68 %.
    Oxygen 29·75 %.
    Water 18·59 %.
17. Bi = 208·02 ?
18. 2·506 l.
19. 935·39 ccm. ?
20. 11·68 l.
21. Δ 9·664.
22. Δ 9·09.
23. Carbon 14·46 %.
    Hydrogen 1·2 %.
    Potassium 11·75 %.
    Antimony 36·14 %.
    Oxygen 33·73 %.
    Water 2·71 %.
24. 970·6 l. !
25. 2·842 l. !
26. 0·04147 gm.

CHAPTER XXI.

THE PHYSICAL PROPERTIES OF THE METALS.—I.

MASS VOLUME AND DENSITY.

1. (α) 4·65 ccm.
   (β) 5·18 ccm.
   (γ) 8·77 ccm.
   (δ) 169·49 ccm.
2. 281·67 ccm.
3. 0·2702 gm.
4. 9·7 gm.
5. 30·73.
6. 1·805 mm.
7. 267 gm.
8. 5 yards ?
9. Δ 8·013.
10. 5·215 tons.
11. 981 kilo. ?
12. 392·07 kilo. ?
13. 8541·22 gm.
14. 78·38 tons.
15. 864 kilo.
16. 3681 gm.

17. 5·3324 cm.
18. 27901·7 times.
19. 6·156 inches.
20. 516·7 gm.
21. 0·01335 mm.
22. 114·668 gm.
23. 889·2 lb.
24. 3062·5 lb.
25. 166 654·4 ?
26. 944·82 ccm.
27. 2·341 l ?
28. 1 mm.
29. 3·776 mm.
30. 2·08 cm.
31. 163·8 lb.
32. 0·00002087 cm.
33. 54·2134 kilo.
34. 11·845 ft.
2809 ccm. ?
35. 12·24 cm.
36. 2·575 kilo.
37. 0·02325 cm.
38. 1·9402 cm.
39. 0·005782 gm.
40. (α) 0·4278 grain.
(β) 3·47447 grains.

Malleability and Ductility.

41. 318·31 m.
42. 3·12 gm.
43. 0·0006828 cm. diam.
44. 0·004014 mm.
45. 6·401 inches.
46. 5181 sem.
47. 0·0023447 mm.
48. 0·00001098 cm.
49. 0·04016 mm.
50. 0·1616 mm.
51. 974·25 gm.
52. 46·048 m.

Tenacity.

53. 8·1 kilo.
54. 68·96 cm.
55. 61·85.
56. 141·8 kilo.
57. 44·45 tons.
58. 4 mm. iron.
59. 62·6 cm.
3·266 mm. nickel.
2·89 mm. cobalt.
60. 286 lb. ?
61. 441·75 kilo.

CHAPTER XXII.

The Physical Properties of Metals.—II.

Alloys.

1. 100 kilo. copper.
12 kilo. tin.
2. 8·71.
3. 7·24.
4. 35 volumes ?
5. 0·000154 gm.
6. 7·16.
7. 3·534.
8. 8·915.

9. 8·027.
10. 11·47.
11. 0·5544 ccm.
12. 10·138.
13. Δ 10·36 if no change.
    101·6 vol.
14. 17·8.

FUSIBILITY.

15. 411·6° C. 1040° C.
16. 82·2° C. 116·6° C. 860° C.
17. 1099·8° C.
18. 1520° C. ?

EXPANSIBILITY.

19. 246·26 yards.
20. 785·133 mm.
21. 767·35 mm.
22. 11409·3 ccm. at 17·5° C.
    11398·17 ccm. at 0° C.
23. 493·886 ccm. ?
24. 13·329.
25. 13·56.
26. 20·1 mm. ?
27. 3·91 ccm.
28. 122° C.
29. 27·5 ccm. ?
30. 0·03663 calorie.
    0·00012486 ccm.
31. 0·9532 ccm.
32. 0·000031.

CHAPTER XXIII.

POTASSIUM.

1. 1769·2 gm. carbonate.
    307·69 gm. carbon.
2. 229·74 l.
3. 1232·1 gm. carbonate.
    660·7 gm. hydrate.
4. 6·06 l. ?
5. 1·616 l.
6. 17·28 gm. ?
7. 136·4 ccm.
8. K_2H.
9. Potassium 35·39 %.
    Silicon 12·89 %.
    Fluorine 51·72 %.
10. Potassium 13·97 %.
    Aluminium 9·67 %.
    Silicon 30·52 %.
    Oxygen 45·84 %.
11. 876·5 gm. chloride.
    1188·2 gm. nitrate.
12. 12·67 l.
13. 1·19 l. oxygen.
    4·76 l. tetroxide.
14. 2536·4 ccm.
15. 33·185 l. at 0° C.
    154·741 l. at 1000° C.
16. 30·7 tons.
17. 1·243 l.
18. 1·067 l.
19. 6·58 at.
20. $KClO_4$.
21. 76 l.
22. 38·18 l.
23. 41·36 l.
24. K = 38·85.

CHAPTER XXIV.

SODIUM.

1. 8·68 kilo. sodium.
   12·68 cub. m. dioxide.
2. 84·37 l.
3. Na = 23·176.
4. 39·204 %.
5. 109·5 ccm. 113·3 ccm.
6. 1·325 k. carbonate.
   0·925 k. lime.

	(α)	(β)
7. Sodium	43·4	16·08 %.
Carbon	11·32	4·19 %.
Oxygen	45·28	16·78 %.
Water		62·93 %.

8. 44·1 % sulphate.
   55·9 % water.
9. 411·9 lb.
10. 453 kilo. ?
11. 121·3 tonnes sulphate.
    126·8. cub. m. chloride.
12. 54·93 gm. sulphide.
    66·56 l. monoxide.
13. 1213·6 kilo. saltcake.
    382·9 cub. m. chloride.
14. 2520 kilo. crystals.
    965·24 kilo. chloride.
15. 1004·1 l.
16. (α) 496 ccm.
    (β) 992 ccm.
17. 95·74 %.
18. (α) 4·348 %, (β) 1·887 % } in excess.
19. $Na_2OAl_2O_36SiO_2$.
20. 17·95 lb.
21. 1·076 l.
22. 1·85 l.
23. 2·714 cm.
24. 0·629 ?
25. (α) 1·1115 gm.
    (β) 0·8165 gm. ?
26. 12·17 % potassium.
    30·51 % sodium.
    57·32 % carbonate.

CHAPTER XXV.

AMMONIUM.

1. NH_4Cl.
2. 6·788 l. ?
3. 437·1 l. ?
4. 36·6 l.
5. 295·4 l. ?
6. 1758·9 gm.
7. 3·63 pints.
8. 26·77 gm.

	(α)	(β)
9. Nitrogen	22·04	35·9 %.
Hydrogen	7·09	7·7 %.
Carbon	14·17	15·4 %.
Oxygen	56·69	41 %.

10. 19·52 gm metaphosphate.
    4·522 l. ammonia.
    44·99 l. steam.

HYDROXYLAMINE.

11. 70·36 l. nitric oxide.
109·277 l. hydrogen.
12. 487·3 ccm of each gas.
13. 2·0685 l. !
14. 557·2 gm. water !
15. 3·682 l. !
937 gm. chloride !
4·878 gm.

CHAPTER XXVI.

CALCIUM.

1. (α) 40. (β) 23·26.
(γ) 51·28. (δ) 17·09.
2. 178·57 tons.
3. 2·017 kilo.
4. 0·62 gm. ?
5. $CaCO_3$.
6. $CaC_2O_4.H_2O$.
7. 604·8 cub. m.
8. 2·486 l.
9. 470154 l.
10. 254000 gal.
11. $x \times 0{\cdot}01586$ gm. ?
12. 26·68 ccm.
13. 2470 gm. ?
14. 13·6 gm.
15. 26·47 ccm.
16. 94·94 gm.
17. 42·366 kilo.
18. 1·88 gm. carbon dioxide.
19. 0·0397 % by vol.
20. 665·2 ccm. ?
21. $CaCl_2 8NH_3$.
22. 9·497 l.

CHAPTER XXVII.

STRONTIUM AND BARIUM.

(α)		(β)		
1. Strontium	59·34	Strontium	47·71 %	2. 539·5 ccm.
Carbon	8·13	Sulphur	17·43 %	3. 489·6 gm.
Oxygen	32·53	Oxygen	34·86 %	4. 0·723 gm.
(γ)		(δ)		5. Sr = 87·5 ?
Barium	69·54	Barium	58·8 %	6. 0·0467.
Carbon	6·09	Sulphur	13·73 %	7. 5·862 kilo.
Oxygen	24·36	Oxygen	27·47 %	8. 2·585 gm.

9. 8·336 gm.
10. 3·254 gm.
11. 186·956 gm.
12. 7·883 l.
13. 8·47 l.
14. 1·062 l.
15. 15·147 l.
16. 1·7132 gm.
17. 24·77 gm. chloride.
2·274 l. dioxide.
18. 69·54 %.
19. 0·04016 gm.
20. 6·27 gm. barium.
0·3894 gm. calcium.

CHAPTER XXVIII.

ALUMINIUM.

1. (α) 24·23 gm.
   (β) 12·85 gm.
   (γ) 24·77 gm.
2. 359·37 gm. sodium.
   140·62 gm. aluminium.
3. 5·897 gm.
4. 3·282 l.
5. 13·8 gm.
6. 0·29605 ccm.
7. Al = 27·05.
8. (α) 4255 gm. ?
   (β) 9294 gm.
9. (α) 11·26 gm.
   (β) 4·944 l.
10. $[FeMg]O[Al_2Fe_2]O_3$.
11. 70·42 l.
12. 269·7 ?
13. 5·679 gm.
14. 15·6 l. ?
15. Al = 27·4.
16. 4·489 l.
17. 13·69 l. !
18. $Al_3Na_5F_{14}$.
19. $Al_6Na_6Si_7S_5O_{27}$.
20. $([FeMg]O)(Al_2O_3)_5(SiO_2)_{30}12H_2O$?

CHAPTER XXIX.

MAGNESIUM.

1. (α) 289·1 gm.
   (β) 132·3 gm.
   (γ) 99· gm.
2.

	(α)	(β)
Magnesium	14·61	26·33 %
Silicon	25·51	20·43 %
Oxygen	38·32	40·29 %
Water	21·56	12·95 %

3. 31·28 gm.
4. 9·71 l.
5. 482·3 gm. sodium.
   255·8 gm. magnesium.
6. 1·975 l.
7. 3·366 l.
8. 79·09 l.
9. Mg = 24·006.
10. 196 ccm.
11. *mg* = 12·2 ?
12. 2·92 kilo. ?
    265·4 l.
13. 42·04 kilo.
14. 75 % calc. carb.
    25 % magn. carb.
15. 15·94 l. !
16. 3·298 %.
17. 1·41 cm. !

CHAPTER XXX.

ZINC.

1. (α) Zinc 67·15 %.
   Sulphur 32·85 %.
   (β) Zinc 52 17 %.
   Carbon 9 57 %.
   Oxygen 38·26 %.
2. $Zn_2SiO_4.H_2O$.
3. (α) (β)
   Carbon 95·6 123·2 gm.
   Monoxide 178·6 330 l. ?
4. 1244·6 gm.
   815·5 l. ?
5. 1642·7 cub. m.
6. 400·4 lb.
7. 183·7 ccm.
8. $zn = 32·4$?
9. 22·234 gm.
10. 14·55 l.

CADMIUM.

11. Cadmium 77·78 %.
    Sulphur 22·22 %.
12. 307·14 gm.
    20 l.
13. $Zn_8C_3O_{14}6H_2O$.
14. $Cd = 112·6$. $CdCl_2$.
15. 290·88 gm. !
16. $Cu_{21}Zn_{15}$.
17. $Zn(C_2H_5)_2$.
18. 10·856 gm.

CHAPTER XXXI.

MANGANESE.

1. (α) 63·2 gm. ? (δ) 22·8 gm.
   (β) 69·6 gm. (ε) 10·95 gm.
   (γ) 63·2 gm.
2. 77·46 gm. manganese.
   31·55 l. monoxide ?
3. Mn = 54·967.
4. Mn = 54·972.
5. 43·54 l.
6. 5·432 l.
7. 42,328 l.
8. 207·1 kilo.
9. (α) 18·39 gm.
   (β) 19·39 gm.
   (γ) 25·316 gm.
10. 4·76 l.
11. 432·47 lb.
12. 85·63 %.
13. 3·6 l.
14. 75·62 %.
15. 43·6 % ?
16. 7·11 l.
17. 0·0007595 gm. ?
18. 3·16 gm.
19. 29·31 gm. !
20. 10 %.

CHAPTER XXXII.

IRON.

1. (α) 72·4 gm. (δ) 48·3 gm. ?
   (β) 70 gm. (ϵ) 46·67 gm.
   (γ) 59·89 gm. (ζ) 56·75 gm.
2. 90 tons.
3. 6578 cub. m.
4. 27·01 l. ?
5. 45·347 l.
6. 1496·6 l.
7. 266·7 ccm.
8. 2·265 ccm.
9. 5·87 l.
   49·75 gm.
10. $fe = 28$.
11. 1330·409 kilo.
12. Fe = 56·06 ?
13. 58·8 gm.
14. (α) 6·79.
    (β) 10·67.
15.

	(α)	(β)
Iron	94·92	97·39 %
Carbon	5·08	2·61 %

16. FeI_25H_2O.
17. $Fe(CO)_5$.
18. 325.
19. 1·545 l.
20. 681·5 ccm.
21. 90·6 l.
22. 2·286 gm.
23. 0·01738 gm.
24. $Fe_23SO_49H_2O$ coquimbite.
25. 27·128 gm.
26. Fe_5N_3.
27. Fe_23SO_4.
28. $(NH_4)_2Fe_24SO_4.14H_2O$.
    $(NH_4)_2Fe2SO_4.6H_2O$.
29. 294·7 gm. iron.
    123·495 l.
30. 91·88 l.
31. 132·22 l.
32. 42·67 l.
33. 16·33 tons.
34. 1·772 permanganate.
    1·14286 dichromate.
35. (α) 0·005316.
    (β) 0·003428.
36. 79·74 % iron.
37. 29·95 % iron.
38. 0·042 gm. iron in 1 ccm.
39. $Fe_{11}O_{12}$.
40. $Fe_4S_3O_{12}$.
41. Fe = 56 ! ?
42.

Iron	18·9 % !
Ferrous oxide	81·1 % !

43.

Carbon combin.	0·627 %
,, graphite	0·102 %
Silicon	0·026 %
Sulphur	0·005 %
Manganese	0·12 %
Iron and loss	99·12 %

CHAPTER XXXIII.

NICKEL.

1. 1247·8 l.
2. 3·215 l.
3. 74·48 gm.
4. 5·185 l.
5. 0·435 gm.
   1·115 l.
6. 0·0309 mm.
7.

Nickel	11·84 %
Potassium	31·84 %
Nitrogen	17·14 %
Oxygen	39·18 %

8. $(NH_3)_2NiSO_4$.

COBALT.

9. CoAsS cobalt-glance.
10. 42·706 l.
11. 128·96 gm. cobalt.
    635·96 l. steam and dioxide.
12. 199·56 l.
13. Potassium 35·24 %.
    Cobalt 17·77 %.
    Carbon 21·69 %.
    Nitrogen 25·3 %.
14. Cobalt 22·73 %.
    Chlorine 41·04 %.
    Nitrogen 26·97 %.
    Hydrogen 5·78 %.
    Water 3·47 %.
15. 4·52 ccm.
16. 1·517 l.
17. $Fe_{12}Ni_3P_5$.
18. $Co_3As_2O_8 8H_2O$.
19. Co = 59·03 !
20. 85·79 % cobalt.

CHAPTER XXXIV.

CHROMIUM.

		(α)	(β)	
1.	Chromium	46·42	68·42	%.
	Iron	25		
	Oxygen	28·58	31·58	%.

2. 111·5 gm. chromium.
   78·92 l. monoxide.
3. 63·99 gm. sodium.
   48·22 gm. chromium.
4. 247·5 gm. zinc.
   131·2 gm. chromium.
5. 14·72 gm. oxide.
   5·426 l. oxygen.
6. 517 gm. oxide.
7. $Cr_2O_3 7H_2O$.
8. $K_3CrC_6O_{12}$.
9. 131·58 gm. sulphide.
   39·11 l. dioxide. ?
10. 746·8 ccm.
11. 5·75.
12. 181·58 l.
13. 94·89 gm.
14. 7·45 l.
15. Cr. = 52·47.
16. Cr = 52·2.
17. 5091·8 gm.

		(α)	(β)	
18.	Chromium	76·4	61·9	%.
	Oxygen	23·5	38·1	%.

CHROMIUM TRIOXIDE.

19. 13·13 tons ?
20. (α) 295·9 ccm. acid.
    (β) 100·9 ,, ,,
21. 857·1 gm.
22. 13·05 l.
23. 124·4 gm.
24. 3·496 l.
25. Potassium 22·35 %.
    Chlorine 20·35 %.
    Chromium 29·8 %.
    Oxygen 27·5 %.

26. $K_2Cr_2O_{10}$.
27. Cr = 52.
28. Cr = 51·977.
29. (α) 0·24 gm. in trioxide.
(β) 0·16326 gm. in dichrom.
30. (α) ·0016326 avail. ox.
(β) ·01143 gm. iron.
(γ) ·01408 gm. lead.
31. 11·04 l.
32. 10·14 l.
33. 11·432 l. nitrogen.
76 gm. oxide.
34. 7·407 l.
35. 16·394 l.
36. 17·92 ccm.
37. 16·67 gm. oxide.
5·02 l. chlorine.
38. 5·3.
1·255 l. oxygen.

CHAPTER XXXV.

TIN.

1. Tin 78·67 %.
Oxygen 21·33 %.
2. $Cu_2Fe\,SnS_4$.
3. 160 kilo. charcoal.
315·07 cub. m. dioxide.
4. Sn = 118·08.
5. Sn = 118.
6. 558·73 l.
7. 6·809 l. ?
8. 179·6 gm. carbonate.
227·1 gm. oxide.
9. Hydrogen 0·84 %.
Tin 74·05 %.
Oxygen 25·1 %.
10. $Na_2SnO_34H_2O$.
11. $H_8Sn_6O_{15}$.
12. 450 gm. tin salts.
46·39 l. hydrogen.
13. 5·907 l.
14. 23·15 l.
15. $SnCl_42NH_4Cl$.
16. 415·82 l. ?
17. 265·6 for $SnCl_4$.
377·6 for Sn_2Cl_4.
18. SnS_2.
19. 11·994 l.
20. 3·558 l. ?
21. 0·2684 gm. ?
22. 0·02632 gm.

CHAPTER XXXVI.

LEAD.

1. (α) 86·6 %.
(β) 77·52 %.
(γ) 68·31 %.
2. 900 kilo. galena.
1818·7 kilo. lead.
207·6 cub. m. dioxide.
3. 38·02 kilo. carbon.
655·88 kilo. lead.
74·3 cub. m. monoxide.
4. 43·63 kilo. litharge ?
2191·3 l. oxygen.
5. 9·558 cub. m.
6. Pb = 207·08.

7. 8·495 l.
8. 270·85 gm.
9. 68·51 l.
10. 27·511 gm.
11. Pb_3O_4.
12. 14·44 gm.
13. $Pb_8Cl_2O_7$.
14. 0·9447 gm. nitrate.
    0·9476 gm. iodide.
15. Pb = 207·1.
16. 21·833 l.
17. Pb = 206·77 ?
18. $PbClC_2H_3O_2$.
19. Lead 64·09 %.
    Chromium 16·1 %.
    Oxygen 19·81 %.
20. $3PbO.2CrO_3$? melanochroite
21. 0·0012866 % lead.
22. 429·1 gm.
23. 4·824 l.
24. 8·046 l.
25. 54·6 %.
26. 588·4 gm. litharge ?
    752·4 ccm. acetate.
27. 1419·4 gm. acetate.
    90·581 l. dioxide.
28. 30·83 l.
29. 8·5 l.
30. Carbonate 68·05 % !
    Hydrate 30·71 % !
    Impurity 1·24 % !
31. $Pb(CH_3)_4$.
32. 596·6 ccm. !

CHAPTER XXXVII.

COPPER.

		(α)	(β)	(γ)
1.	Copper	45·43	57·39	55·21 %.
	Carbon	8·63	5·44	6·98 %.
	Oxygen	45·94	29·01	32·57 %.
	Water		8·16	5·23 %.

2. $CuSiO_3 2H_2O$. chrysocolla.
3. 28·6 gm.
4. 52·1. gm.
5. 1837·8 gm.
    1236 l.
6. Cu = 63·17 ?
7. 25·46 gm. copper.
    18·91 l. steam.
8. 1·4094 gm.
9. 117·06 gm.
10. 14·86 gm. copper.
    46·4 gm. chloride.
11. 200·1.
12. 38·07 l.
13. $CuCl_2.3CuO.4H_2O$.
    Atacamite.
14. $CuSO_4 3CuH_2O_2$.
15. 9·473 l.
16. 3938·3 gm. sulphate.
    370·72 l. dioxide.
17. 142·7 ccm. sulphate ?
    84·77 gm. copper.
18. 0·6393 gm. ?
19. 26·1 % copper.
20. (α) 10·15 %. (δ) 40·4 %.
    (β) 18·43 %. (ε) 44·16 %.
    (γ) 36·1 %.
21. 1·3857 l.
22. 469·4 gm.
23. $CuCO_3H_2CuO_2$.
24. 20·012 l. ?
25. 1·4547 l.
26. Cu = 63·68.

CHAPTER XXXVIII.

MERCURY.

1. 6896·55 gm. mercury.
   809·2 l. dioxide.
2. 201·4.
3. Hg = 199·8.
4. sp. ht. 0·03448.
5. 40 % sodium.
6. Hg_2Cd.
7. 19·47 atmos.
8. $Hg(C_2H_5)_2$.
9. 4·014 l.
10. 38·524 gm.
11. 94·36 ccm. mercury.
    1·72 kilo. chloride.
12. 237.
13. 292·5 gm. salt.
    677·5 gm. chloride.
14. $HgCl_2.2H_4NCl.H_2O$.
    Sal alembroth.
15. 2·6507 gm.
16. 11·392 l.
17. 110·89 l.
18. Mercury 71·68 %.
    Hydrogen 0·36 %.
    Nitrogen 5·02 %.
    Oxygen 22·94 %.
19. Mercury 82·42 %.
    Sulphur 4·39 %.
    Oxygen 13·19 %.
20. 59·2 gm. sulphate.
    5·12 l. dioxide.
21. Hg = 200·14.
22. 464·3 gm. pot. iodide.
    634·9 gm. merc. iodide.

CHAPTER XXXIX.

SILVER.

1. (α) Silver 75·26 %.
    Chlorine 24·74 %.
    (β) Silver 87·1 %.
    Sulphur 12·9 %.
2. Ag_3AsS_3.
3. (α) 9·366 lb. iron.
    (β) 66·9 lb. mercury.
4. 272,180 l.
5. 2·195 l.
6. 182·9 % by vol.
    0·02485 % by mass.
7. Ag = 107·04 !
8. 194235 shillings ? 1·0815 ton.
9. Ag_3Cu_2.
10. Ag_2Hg_3.
11. 535·8 ccm.
12. (α) 544·1 ccm.
    542 ccm. !
    (β) 272 ccm.
13. 441·37 ccm.
14. (α) 99·9 ccm. ?
    (β) 199·8 ccm. ?
15. Silver 85·71 %.
    Hydrogen 0·4 %.
    Oxygen 6·35 %.
    Fluorine 7·54 %.
16. Ag = 107·98.
17. Ag = 107·99.
18. 184·66 gm.
19. 5·4167 gm.
20. $2AgCl.3NH_3$ 95·7 gm. chloride.
    $7AgCl.10NH_3$ 100·45 ,, ,,
    $16AgCl.23NH_3$ 99·82 ,, ,,
21. 77·15 gm.
22. 8·775 l.
23. 703·4 gm. sulphate.
    53·895 l. dioxide.
24. 755·5 gm. nitrate.
    35·25 l. oxide.

CHAPTER XL.

GOLD.

1. 138759·84 sovs.
   1·0909 ton.
2. Au_7Cu_2. 91·57 % gold.
3. 424·2 gm.
4. Au = 196·1.
5. 2·747 gm.
6. 336 ccm.
7. 31·8 ccm.
8. AuO.
9. $Au_2O_3.4NH_3$.
   Fulminating gold.
10. $(SnO_2)_2SnOAu_2O4H_2O$.
11. 2·703 gm.
12. 30·83 gm.
13. Nitrogen 3·73 %.
    Hydrogen 1·07 %.
    Gold 52·48 %.
    Chlorine 37·91 %.
    Water 4·81 %.
14. 5·5427 gm.
15. 38·287 gm. chloride.
    3·9793 l. chlorine.
16. 6·4863 gm. gold.
    2·3227 l. dioxide.

PLATINUM.

17. 43·92 gm. ?
18. 23·14 gm.
19. $Pt_{11}As_{21}$.
    73·43 gm. arsenic.
20. 864·1 gm.
21. 817·53 ccm.
22. 37·88 gm. chloride.
    3·354 l. chlorine.
23. 172·18 gm.
24. 10·52 gm.
25. Potassium 16·05 %.
    Platinum 40·12 %.
    Chlorine 43·83 %.
26. Pt = 197·4.
27. Pt = 195·27.
28. Nitrogen 9·3 %.
    Hydrogen 2 %.
    Platinum 65 %.
    Chlorine 23·6 %.
29. $N_4H_{12}PtCl_4$.

TABLES.

TABLE I.—ATOMIC WEIGHTS.

Aluminium	Al.	27	Iron	Fe.	56
Antimony	Sb.	120	Lead	Pb.	207
Arsenic	As.	75	Magnesium	Mg.	24·4
Barium	Ba.	137	Manganese	Mn.	55
Bismuth	Bi.	208	Mercury	Hg.	200
Boron	B.	11	Nickel	Ni.	58
Bromine	Br.	80	Nitrogen	N.	14
Cadmium	Cd.	112	Oxygen	O.	16
Calcium	Ca.	40	Phosphorus	P.	31
Carbon	C.	12	Platinum	Pt.	195
Chlorine	Cl.	35·5	Potassium	K.	39
Chromium	Cr.	52	Silicon	Si.	28·4
Cobalt	Co.	59	Silver	Ag.	108
Copper	Cu.	63·3	Sodium	Na.	23
Fluorine	F.	19	Strontium	Sr.	87·6
Gold	Au.	196·6	Sulphur	S.	32
Hydrogen	H.	1	Tin	Sn.	118
Iodine	I.	127	Zinc	Zn.	65·4

TABLE II.—MEASURES.

(i.) *Of Length* (*English*).

The YARD is the distance at 62° F. between two marks on a bronze bar deposited with the Board of Trade.

1 inch.
12 inches = 1 foot.
36 inches = 3 feet = 1 YARD.
63,360 inches = 5280 feet = 1760 yards = 1 statute mile.

A knot or geographical mile is the mean length on the Equator subtended by one minute of longitude, and is equal to about 6087 feet or 1·152 statute miles.

(ii.) *Of Length* (*Metric*).

The METRE is the length at 0° C. of a platinum bar kept at Paris and known as the "Mètre des Archives."

1 millimetre (mm.).
10 mm. = 1 centimetre (cm.).
100 mm. = 10 cm. = 1 decimetre (dm.).
1000 mm. = 100 cm. = 10 dm. = 1 METRE (m.).
10 m. = 1 decametre.
100 m. = 10 decametres = 1 hectometre. [kilom.
1000 m. = 100 decametres = 10 hectometres = 1 kilometre

The metre was intended to be 0·0000001 of the quadrant of the globe passing through Paris. The standard metre is about 0·00015 shorter than it was intended to be.

(iii.) *Of Length* (*Conversion*).

1 inch = 0·0254 m.	1 mm. = 0·03937 inch.
1 foot = 0·3048 m.	1 metre = 39·371 inches.
1 yard = 0·9144 m.	1 metre = 3·2809 feet.
1 mile = 1·6093 kilom.	1 metre = 1·0936 yard.
1 knot = 1·855 kilom.	1 kilom. = 0·6214 mile.

(iv.) *Of Area or Surface* (*English*).

1 square inch.
144 sq. inches = 1 square foot.
1296 sq. inches = 9 sq. feet = 1 sq. yard.
43,560 sq. feet = 4840 sq. yards = 1 acre.
640 acres = 1 square mile.

(v.) *Of Area* (*Metric*).

1 square millimetre (smm.)
100 smm. = 1 square centimetre (scm.).
10,000 smm. = 100 scm. = 1 square decimetre (sdm.).
1,000,000 smm. = 10,000 scm. = 100 sdm. = 1 square metre (sm.).
10,000 (sm.) = 100 ares = 1 hectare.

(vi.) *Of Area* (*Conversion*).

1 sq. inch = 6·451 scm.	1 scm. = 0·155 sq. inch.
1 sq. foot = 929·0 scm.	1 sm. = 10·764 sq. feet.
1 sq. yard = 0·8361 sm.	1 sm. = 1·196 sq. yards.
1 acre = 4046·7 sm.	1 hectare = 2·471 acres.
1 sq. mile = 2·59 sq. kilom.	1 sq. kilom. = 0·3861 sq. mile.

(vii.) *Of Volume or Capacity* (*English*).

A GALLON is the volume occupied by 10 lb. of water at 62° F.

1 cubic inch.
34·659 cub. inches = 1 pint.
277·274 cub. inches = 8 pt. = 1 GALLON = 0·16046 cub. foot.
1728 cub. inches = 49·857 pt. = 6·2321 gal. = 1 cub. foot.
27 cub. feet = 1 cubic yard.

(viii.) *Of Volume* (*Metric*).

A LITRE is the volume occupied by a kilogram of water at 4° C. It is very nearly a cubic decimetre.

1 cubic centimetre (ccm.).
1,000 ccm. = 1 LITRE (cubic decimetre) (l.).
1,000,000 ccm. = 1000 l. = 1 stere (cubic metre).

(ix.) *Of Volume* (*Conversion*).

1 cub. inch	= 16·386 ccm.	1 ccm.	= 0·06103 cub. inch.
1 pint	= 0·5679 l.	1 l.	= 61·027 cub. inch.
1 gallon	= 4·54346 l.	1 l.	= 0·2201 gal.
1 cub. ft.	= 28·315 l.	1 l.	= 0·03532 cub. ft.
1 cub. yard	= 0·7645 cub. m.	1 stere	= 1·308 cub. yard.

(x.) *Of Mass* (*English*).

A POUND is the mass of a certain piece of platinum deposited with the Board of Trade.

1 grain (gn.)
437·5 gn. = 1 ounce (oz.).
7000 gn. = 16 oz. = 1 POUND (lb.).
2240 lb. = 20 hundredweight (cwt.) = 1 ton.
1 pound troy = 12 ounces troy = 5760 gn. = 0·823 lb.

A cubic foot of water at 4° C. weighs about 62·4 lb., or 1 lb. of water occupies about 0·01602 of a cubic foot.

(xi.) *Of Mass* (*Metric*).

The KILOGRAM is the mass of a piece of platinum at Paris known as the "Kilogramme des Archives."

1 milligram (mgm.).
10 mgm. = 1 centigram (cgm.).
100 mgm. = 10 cgm. = 1 decigram (dgm.).
1000 mgm. = 100 cgm. = 10 dgm. = 1 gram (gm.).
1000 gm. = 1 KILOGRAM (kilog.).
1,000,000 gm. = 1000 kilog. = 1 tonne.

The gram was intended to be and very nearly is the mass of 1 ccm. of water at 4° C. Hence a litre of water weighs about 1 kilog.

(xii.) *Of Mass* (*Conversion*).

1 grain	=	0·0648 gm.	1 gram	=	15·432 grains.
1 oz.	=	28·35 gm.	1 kilog.	=	2·2046 lb.
1 oz. troy	=	31·1 gm.	1 tonne	=	0·9842 ton.
1 lb.	=	453·593 gm.			
1 cwt.	=	50·8 kilog.			
1 ton	=	1016·05 kilog.			

TABLE III.—MENSURATION.

$\pi = 3{\cdot}1416.$ $\qquad \frac{1}{\pi} = 0{\cdot}3183.$

A right-angle = 90 degrees (°) = 5400 minutes (′) = 324,000 seconds (″).

A radian $= \frac{180°}{\pi} = 57{\cdot}3° = 206{,}264{\cdot}8''.$

Length.

1. Circle, radius r ..... $L = 2\pi r$.

Plane Areas.

1. Square, side a ..... $A = a^2$.
2. Triangle, base c, perpendicular d..... $A = \frac{1}{2}cd$.
3. Rectangle, sides a, b ..... $A = ab$.
4. Circle, radius r ..... $A = \pi r^2$.
5. Ellipse, semiaxes a, b..... $A = \pi ab$.

Surfaces.

1. Cube, edge a ..... $S = 6a^2$.
2. Sphere, radius r..... $S = 4\pi r^2$.
3. Cylinder, radius r, height h..... $S = 2\pi r(r + h)$.
4. Spherical segment, radius r, height h..... $S = 2\pi rh$.
5. Cone, slant height l, radius r ..... $S = \pi r(r + l)$.

Volumes.

1. Cube, edge a ..... $V = a^3$.
2. Rectangular parallelopiped, edges a, b, c.... $V = abc$.
3. Sphere, radius r ..... $V = \frac{4}{3}\pi r^3$.
4. Spheroid, radii a, b, b ..... $V = \frac{4}{3}\pi ab^2$.
5. Cylinder or prism ..... $V =$ area of base × height.
6. Cone or pyramid .... $V = \frac{1}{3}$ area of base × height.

TABLE IV.—TENSION OF AQUEOUS VAPOUR IN MM. OF MERCURY.

$t°$ C.	mm.	$t°$ C.	mm.	$t°$ C	mm.	$t°$ C	mm.
0	4·6	10	9·1	20	17·4	30	31·5
1	4·9	11	9·8	21	18·5	40	54·9
2	5·3	12	10·4	22	19·6	50	92·0
3	5·7	13	11·1	23	20·9	60	148·9
4	6·1	14	11·9	24	22·2	70	233·3
5	6·5	15	12·7	25	23·5	80	354·9
6	7·0	16	13·5	26	25·0	90	525·5
7	7·5	17	14·4	27	26·5	100	760·0
8	8·0	18	15·3	28	28·1		
9	8·5	19	16·3	29	29·7		

TABLE V.—MISCELLANEOUS DATA.

N.B.—The gases are "normal" *and the mercury at* 0° *C.*

Pressure of the air in grams on the scm.	1033·3.
,, ,, pounds on the square inch....	14·7.
,, ,, mm. of mercury	760
Grams in a litre of mercury	13596
,, ,, hydrogen	0·0896.
,, ,, air	1·293.
Pounds in a cubic foot of hydrogen	0·005592.
,, ,, ,, air	0·080728.
Density of aqueous vapour (Air = 1.) ($\frac{5}{8}$?)	0·62344.
Litres occupied by a number of grams of any gas equal to the molecular weight	22·4 ? 22·32 !
Grams of air in 22·32 l.	28·872.
Percentage of oxygen in air by volume	21
,, ,, ,, mass	23·3.
,, of carbon dioxide in air by volume	0·04.
Latent heat of water	79
,, of steam	536
Coefficient of expansion of a gas when heated from 0° C. to 1° C.	$\frac{1}{273}$? 0·00367 !
Coefficient of expansion of mercury for 1° C.	$\frac{1}{5550}$.
,, ,, ,, in glass	$\frac{1}{6480}$.

TABLE VI.

The Logarithms of $1 + \cdot00367\,t$.

t° C.	Log.	D.	t° C.	Log.	D.	t° C.	Log.	D.
					11			8
−30	$\bar{1}\cdot9493$	18	120	·1585		255	·2869	
			125	·1640		260	·2910	
−20	$\bar{1}\cdot9669$	17	130	·1694		265	·2950	
−10	$\bar{1}\cdot9838$	16	135	·1748	11	270	·2991	
0	·0000		140	·1801	10	275	·3030	
5	·0079	16	145	·1853		280	·3070	
10	·0157	15	150	·1905		285	·3109	
15	·0233		155	·1956		290	·3148	
20	·0308		160	·2006		295	·3186	8
25	·0381	15	165	·2056		300	·3224	7
30	·0454	14	170	·2106		305	·3262	
35	·0525		175	·2154	10	310	·3299	
40	·0595		180	·2203	9	315	·3337	
45	·0664	14	185	·2250		320	·3373	
50	·0732	13	190	·2298		325	·3410	
55	·0799		195	·2344		330	·3446	
60	·0864		200	·2391		335	·3482	
65	·0929		205	·2436		340	·3518	
70	·0993	13	210	·2481		345	·3553	7
75	·1056	12	215	·2526		350	·3588	
80	·1118		220	·2571				
85	·1179		225	·2614		440	·4174	
90	·1240		230	·2658				
95	·1299	12	235	·2701		860	·6187	
100	·1358	11	240	·2743	9			
105	·1416		245	·2786	8	1040	·6828	
110	·1473		250	·2827				
115	·1529	11			8			

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	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21	25	29	33	37
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19	23	26	30	34
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17	21	24	28	31
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
14	1461	1492	1528	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	18	21	24	27
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14	17	20	22	25
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31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
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34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
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42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
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55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
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58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
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60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
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65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
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67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
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72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	5	5
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82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
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84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3	3	4	4	5
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86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3	3	4	4	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
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92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2	3	3	4	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	3	4

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